Mine Ventilation Made Easy.

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UNITED STATES OF AMERICA.

MINE VENTILATION

MADE EASY,

WITH AN APPENDIX CONTAINING DETAILED

ANSWERS TO 155 QUESTIONS,

SELECTED FROM VARIOUS

AMERICAN EXAMINATIONS

FOR

MINE INSPECTORS AND MINE FOREMEN.

BY

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PREFACE.

In preparing this little work on Mine Ventilation, the author's object was the production of a thorough but concise work for the use of American mine officials and mining students. It is therefore written in as simple language as possible, and the principles of ventilation are carefully adapted to meet the conditions existing in American mines. The work was originally written for publication in THE COLLIERY ENGINEER during the author's engagement as assistant editor of that journal, and while he was residing in the United States, and had every opportunity to learn the wants of American miners.

When the work was completed, at the suggestion of the editors of THE COLLIERY ENGINEER, questions asked at all the State examinations of candidates for mine inspectorships and for certificates of competency as mine foremen, were collected. From these, one hundred and fifty-five were selected and answers to them prepared. These questions and answers form an appendix to this volume. They will be found very useful to students preparing themselves for examinations.

INDEX.

Chapter I.

Facts, Rules, Scientific Memoranda and Maxims, Relating to Air, Gases, Colliery Explosions, and the Ventilation of Mines.

		PAGE
1.	Pure Atmospheric Air	11
2.	Mean Temperature of Air	11
3.	Weight of Air	11
4.	Pressure of the Atmosphere	11
5.	Weight of Air at different Elevations	12
6.	Height of Columns of Air, Water and Mercury to balance each other	12
7.	Height above Sea Level at which Man can exist	12
8.	Comparative weights of Air and Water	12
9.	Barometer and Atmospheric Pressure	12
10.	Increase of Atmospheric Pressure, with Depth	12
11.	Decrease of Atmospheric Pressure and Temperature on ascending	12
12.	Increase of Temperature below surface of the earth	12
14.	Definition of Mine Ventilation	13
15.	Laws of Pennsylvania in regard to Ventilation	13
16.	Principle of Mine Ventilation	13
17.	Natural Ventilation	13
18.	Method by which Furnaces and Fans produce Ventilation	13
19.	Furnace Ventilation	14
20–21.	Dangers of, and Objections to Furnace Ventilation	14
22.	Cost of Furnace Ventilation	15
23.	Dumb-drift	15

		PAGE
24.	Ventilating Fans	15
25.	Tabulated Results of Experiments with the Capell Fan	16
26.	Tabulated Results of Experiments with the Guibal Fan	16
27.	Tabulated Results of Experiments with the Waddle Fan	17
28–29.	The Relations between Power, Pressure and Quantity	18
30–31–32.	Relative Power for different sized Airways (Tabulated)	18
33.	Effect of Splitting the air, and Pennsylvania Laws upon same	19
34.	Regulation of quantities in different Splits	19
35.	To Ascertain Air pressure (Table)	20
36.	Proper Velocity of Air	20
37–38.	Ventilating single places and tunnels	20
39–40.	Expansion of Gases in Goaves on change of Atmospheric pressure	21
41.	Weights of Mercury, Water, Air and Fire-Damp Compared	22
42.	Blowers	22
43–44.	Volcanic disturbances and the issue of Gas	23
45–45½.	Blasting, and the Laws of Pennsylvania regarding the same	23
46.	Ascensional Ventilation	23
47–48.	Ventilation of Shallow and Deep Pits	24
49–50.	Effects of Wind and Weather on Ventilation	24
51–54.	Remarks on Ventilation	24
55.	Diffusion of Gas	24
56.	Walling back Gas	25
57.	Proper place for Stoppings	25
58.	Safety Lamps	25
59–60.	Rules for Gaseous Mines	25
61.	Mixed Lights	25
62.	How to act in case of Explosion	25
63.	Removal of Fire-Damp	26
64.	Relative number of Accidents on different Days of the week	26
65.	Ventilation Plans	26

PAGE

66. Percentages of Accidents from different causes 26
67. Explosive Gaseous Mixtures 27
68. Suffocation by Fire-Damp 27
69. Carbonic Acid Gas 27
70. Carbonic Oxide 27
71. Carbureted Hydrogen 28
72. Olefiant Gas 28
73. Sulphureted Hydrogen 28
74. Sulphurous Acid Gas 28
75. After-Damp 28
76. Gob-Fires 29
77–78. Natural Gas 29

CHAPTER II.

Explanation of Terms Used in the Subject of Mine Ventilation 31 to 47

CHAPTER III.

Practical Notes on Coal Dust and Colliery Explosions 48 to 52

CHAPTER IV.

Rules and Formulæ Applicable to Various Questions Relating to the Ventilation of Mines, the Pressure and Temperature of the Atmosphere, and to the Circulation of Air in Passages, etc.

The Co-efficient of Friction 52
I. Rules applying to Air Moving in Underground Passages 53
II. To ascertain the Motive Column 54
III. Diameter of Round Air-way to pass same Quantity as Square One 54
IV. Relative Pressure to pass equal Quantities, with different Areas or Perimeters 55
V. Relative Quantities that will pass Air-ways subject to same Pressure but of different dimensions 55

PAGE

VI. To reduce a continuous undivided Road of Various dimensions, to one typical Road of Uniform size throughout 55
VII. To convert French to English Co-efficient of friction 55
VIII. To find Quantity of Air with a given Horse power and efficiency of engine 55
IX. To find the Weight of a cubic foot of Air at any Temperature or Height of Barometer 55
X. To convert Thermometer Scales of Fahrenheit, Centigrade and Réaumur into each other 56
XI. To measure Air in a Mine by Gunpowder 56
XII. Formulæ relating to Equivalent Orifice 56
XIII. Formulæ relating to Theoretical Depression, or pressure of Air due to Final Velocity 56
XIV. Relation between Quantities of Air Produced by two fans working Separately and Together 57

Chapter V.

Useful Tables Relating to Mine Ventilation, Air and Gases.

I. Table of the Co-efficient of friction in the flow of Air through Passages with different kinds of surface according to different Authorities, expressed in terms agreeable to the Measures used in the United States, Great Britain, France and Germany 58
II. Table showing the pressure per square foot in pounds due to the Flow of Air at different Velocities in Roads of different dimensions 59
III. Table showing the Quantity of Air that will flow through a passage one foot area, at different velocities, and the pressure due to a length of one mile 59
IV. Table showing length of roads of different dimensions offering resistance equal to one inch of water gauge 60
V. Table showing the water-gauge due to 30,000 cubic feet of Air passing through Mines with different equivalent orifices 61

PAGE

VI. Table of the values of the theoretical depression expressed in inches of water-gauge and head of Air in feet 61
VII. Table of Elementary and Compound Gases, with their properties 62
VIII. Table of the weight of a cubic foot of Air, in Decimals of a Pound, at different Temperatures 63
IX. Table showing comparative composition of Lignite, Bituminous Coal, Anthracite Coal, Wood and Peat 64
X. Table showing Square Root of Water-gauge readings and Pressures 65
XI. Table of the Volume, Density, and Pressure of Air at Various Temperatures 66
XII. Table showing the relative Variations in Mercury, Water and Gas by changes of Atmospheric Pressure 67
XIII. Table showing the Pressure of the Atmosphere per square inch and per square foot at various readings of the Barometer 67
XIV. Table to Illustrate the Chemical Change which takes place in Breathing 68
XV. Table of Analyses of Different Compound Gases 68
XVI. Table of Analyses of Coal Gas from Cannel Coal 69
XVII. Table of Analyses of Coal Gas from Bituminous Coal 70
XVIII. Table of the Expansion of Air by Heat 70
XIX. Table showing the pressure of Air in Shafts, per square foot of Area at Various Depths and Temperatures 71
XX. Table showing Barometric readings corresponding with different Altitudes, in French and English Measures 72
XXI. Table of Comparative Readings of Thermometer on the different Scales—Centigrade, Réaumur and Fahrenheit 72
XXII. Table of Velocities and Pressures of Air 73
XXIII. Table showing the Quantity of gas in cubic feet obtained from Coal 74

PAGE

XXIV. Table showing the Conversion of Column of Water to Column of Mercury and Fire-Damp.. 74

XXV. Table showing the relative weight of Water and Air at different Temperatures, with deductions made therefrom 75

Chapter VI.

Legislation on the Subject of Mine Ventilation in the United States and Foreign Countries.

Prussia 76
England 77
Nova Scotia 77
Victoria 78
Anthracite Law of Pennsylvania 78
Bituminous Law of Pennsylvania 78
Ohio 78
Iowa 79
Washington 79
Tennessee 79
West Virginia 79
Kentucky 79
Alabama 79
Kansas 79
Arkansas 80
Indiana 80
Territories 80

Appendix.

Questions and Answers on subjects relating to Mine Ventilation, Atmospheric Air and Gases, mainly selected from various American Examinations for Mine Inspectors and Mine Foremen ..... 81 to 110

MINE VENTILATION MADE EASY.

CHAPTER I.

FACTS, RULES, SCIENTIFIC MEMORANDA AND MAXIMS RELATING TO AIR, GASES, COLLIERY EXPLOSIONS, AND THE VENTILATION OF MINES.

1. Pure atmospheric air consists of a mechanical mixture of seventy-seven parts, by weight, of nitrogen and twenty-three of oxygen, with small portions of carbonic acid and ammonia, and a varying proportion of watery vapor.

Many impurities have been found in the air of towns by examining the rains which have fallen. The air at the sea-coast, and at great heights, is the freest from impurities, and the porportion of ammonia is found to decrease in ascending. The organic matter contained in the air depends very much upon the density of the population. The return air of mines is often very much vitiated in its passage through the excavations.

2. The mean temperature of the air in Philadelphia is 68·6 degrees Fahrenheit in summer, and 38·3 degrees Fahrenheit in winter. The temperature of air in the interior of mines, especially deep mines, is pretty nearly constant all the year round; this fact, coupled with that of the variation of temperature at the surface, accounts for the uncertainty of natural ventilation.

3. The weight of air is about 31 grains per 100 cubic inches at ordinary pressure and temperature, but it varies according to the reading of the barometer. It becomes less and less in weight as we ascend; the weight of a cubic foot at sea-level under ordinary conditions is ·076097 pound. It becomes lighter as the temperature increases; thus, 1000 cubic feet at 32 degrees Fahrenheit weigh 81 lbs.; at 110 degrees 1000 feet weigh 70 lbs.; and at 200 degrees, 60 lbs.

4. The average pressure of the atmosphere at the level of the sea, is equal to 14·7 lbs. per square inch, or 2116·8 lbs. per square foot. The total pressure on the convex surface of the

earth was calculated by the late Dr. Olinthus Gregory to amount to 10,686,000,000 hundreds of millions of pounds. This may be expressed as ten trillions, six hundred and eighty-six thousand billions. Sir John Herschel's calculation of this was $11\frac{2}{3}$ trillions of pounds, which is about ten per cent. more than that of Dr. Gregory.

5. It is calculated that at a height of about $3\frac{1}{2}$ miles above the sea-level the weight of a cubic foot of air is only one-half what it is at the surface of the earth, at seven miles only one-fourth, at fourteen miles only one-sixteenth, at twenty-one miles only one sixty-fourth, and at a height of over forty-five miles it becomes so attenuated as to have no appreciable weight.

6. The opinion is generally held that atmospheric air encircles the earth for a distance of forty-five miles from the surface, and that a column of air that height, one of water 32 to 34 ft. high, and one of mercury about 30 inches high, on an average balance each other.

7. A man cannot breathe at a greater height than seven miles from the surface. On one occasion when Mr. Glaisher, the celebrated aeronaut, had attained a height of over four miles in a balloon, his hands became quite blue, and he experienced a qualmish sensation in the brain and stomach, resembling the approach of sea-sickness,—great cold and a difficulty of breathing were likewise felt.

8. Air is 821 times lighter than water; the student may calculate this for himself from the following data—air in ordinary conditions weighs ·076097 lb. per cubic foot, water 62·5 lbs., then dividing one into the other he will get 821.

9. A fall in the barometer of one inch represents a reduction in the pressure of the atmosphere of half a pound per square inch or 72 lbs. per square foot, so that an underground excavation six feet square, with an increase of an inch in the barometer, has an increased pressure on the face, of 2592 pounds.

10. The pressure of the atmosphere increases with the depth of shafts, equal to about one inch rise in the barometer for each 150 fathoms (900 ft.) increase in depth: this may be taken by practical miners as a rough and ready rule for ascertaining the depth of shafts.

11. Both the barometer and thermometer show a lower reading in ascending from the surface; for example, at a height of 20,000 feet, the temperature is 40 degrees less than at the surface, and the reading of the barometer is only about one-half of the reading at the surface, but the variation both in temperature and pressure is not regular. In the month of August, on one occasion, Mr. Glaisher found the temperature to be 24 degrees at a height of 23,000 feet.

12. It is generally reckoned that the temperature of the rocks composing the earth gradually increases in descending from the surface, at the rate of one degree on the Fahrenheit scale for

every 60 feet increase in depth, but different results have been obtained by various observers on the question.

14. Mine ventilation is understood to mean the provision for a constant supply of fresh air, and its regular flow throughout the underground workings, in a sufficiently copious quantity to destroy the vitiating effects of the carbonic acid, and water, added to it by the breathing of animals and burning of lights, by the gases issuing from the rocks, or by any other noxious emanations, all of which should be carried away as fast as they are engendered.

15. Although 666 cubic feet of air have been reckoned sufficient to sustain a man for twenty-four hours, much more than that should be reckoned upon. By section 7, Article X., of the Anthracite Mine Law of Pennsylvania, 1891, it is provided that: "All air passages shall be of a sufficient area to allow the free passage of not less than two hundred (200) cubic feet of air per minute for every person working therein."

Section 1, of Article IV., of An Act Relating to the Bituminous Coal Mines of Pennsylvania, approved May 15th, 1893, provides that: "The operator or superintendent of every bituminous coal mine, whether shaft, slope or drift, shall provide and hereafter maintain ample means of ventilation for the circulation of air through the main-entries, cross-entries and all other working places to an extent that will dilute, carry off and render harmless the noxious or dangerous gases generated in the mine, affording not less than one hundred (100) cubic feet per minute for each and every person employed therein, but in a mine where fire-damp has been detected the minimum shall be one hundred and fifty (150) cubic feet per minute for each person employed therein, and as much more in either case as one or more of the mine inspectors may deem requisite."

16. In order to create and maintain a circulation of air through a mine, it is necessary to have at least one inlet and one outlet, and sufficient passages between them for the flow of air, all of sufficient size, and either to rarefy the air-current by heat or to exhaust or pump it out at one end—that is the outlet column—or to compress the air in the inlet column to obtain sufficient pressure.

17. The ventilating pressure necessary for putting air in motion may be obtained by either natural or artificial means. Natural ventilation, on account of the change of the weather, both as regards the direction and force of the wind, and variation in barometer and thermometer, is uncertain and unreliable, particularly in shallow mines, and need not be further referred to here. The artificial means used are generally furnaces and fans or mechanical ventilators.

18. Both furnaces and fans have the same effect in producing ventilation—that is to say, their operation results in altering the density of the air at one end of the column, thus destroying the equilibrium of pressure in the downcast and upcast shafts;

and so long as the pressure is maintained by the means applied, the movement of the air will be continued in the direction to where it is most attenuated.

19. The ventilating pressure obtained by a furnace depends mainly upon the amount of heat communicated to the air-current in the upcast, the depth of the shafts, and the area provided for the escape of the heated air; and for the current to be regular, it is necessary that the furnace should be kept constantly at about the same degree of heat. In furnace ventilation the temperature of the air in the downcast is seldom below 40 degrees, and rarely averages more than 200 degrees in the upcast; this gives a pressure of 11·6 at a depth of 200 yards; of 17·4 at 300 yards; and of 23·2 per square foot at 400 yards. (See Table "Showing Pressure of Air in Shafts," in a subsequent chapter.)

20. There is great risk of fire and of explosions in the use of furnaces, but the rapidity with which the use of mechanical appliances has been extended to the ventilation of coal mines of late years shows that eventually the furnace will fall altogether into disuse; as it may well do from the many dangers and inconveniences attending it.

The use of furnaces is forbidden under the 1891 Anthracite Mine Law of Pennsylvania—the section referring to the matter reads as follows:

"It shall not be lawful to use a furnace for the purpose of ventilating any mine wherein explosive gases are generated."

In the mines of Great Britain, according to General Rule 2, if the mines are gaseous, furnaces are not prohibited, but the return air is to be carried off clear of the fire by means of a dumb-drift.

21. Another objection to the furnace is, that the fumes arising from it eat away the metal casing of the shafts, and injure the wire ropes when coal is wound through the upcast. Mr. Daglish thoroughly explained this before a meeting of the North of England Institute of Engineers in 1859, when he said the injury was not owing to the direct action of the heat of the furnace itself, but to the chemical effect of its vapors principally in action opposite the entrance of the furnace drift into the shaft. "The sulphur in the coals volatilized by the furnace, combines with a portion of oxygen to form sulphurous acid; this, possessing the property of taking up another atom of oxygen when in contact with moist air, forms hydrated sulphuric acid in the upcast shaft, which, diluted with the other shaft-water, passes down the rope, and as the boiling point of hydrated sulphuric acid is greatly higher than that of water, the solution increases in strength as it falls down the shaft, and becomes highly concentrated and corrosive when opposite the furnace drift, and subjected to a temperature of probably 300 degrees. Water after passing down a deep and moist up-

cast shaft is sensibly acid to the taste and reddens litmus paper."

22. Furnace ventilation cannot in point of economy successfully compete with mechanical ventilation. As to the cost per horse-power in the air per hour, the late Mr. Morison showed that with furnaces it varied from the third of a penny to three pence half-penny, whereas with fans the working cost was only half a farthing; that is roughly speaking, the working of furnaces costs four cents, and the working of fans one-fourth of a cent per horse-power. (Transactions of North of England Institute of Engineers, Vol. XIX.)

23. The dumb-drift which was adopted in English coal mines more than fifty years ago for ensuring safety in furnace ventilation, very much reduces the power of the furnace, because it decreases the length of the heated air column; and there is likewise the additional friction in the upcast of the air which feeds the furnace, but which does not circulate through the mine. A furnace probably heats the air up to 300° F., whereas, the temperature of the return air passing up the dumb-drift, in all likelihood does not amount to more than 90° ; there is, therefore, a loss of the extra heat of the furnace, so far up the shaft, as the air enters it from the dumb-drift; the length of the heated column of air being reduced by the vertical distance from the furnace-level to where the dumb-drift enters the upcast as shown Fig. 1, because the main body of air travels along the dumb-drift, and not over the furnace. Of course, it is understood in such a case that the furnace is only supplied by a scale of air simply sufficient to promote combustion.

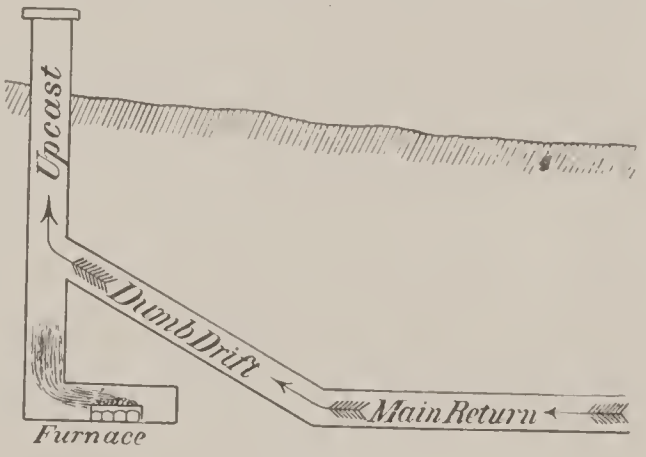

FIG. 1.

24. There are two classes of fans—namely: that which forces the air into the mine, and that which exhausts it from the mine; but the latter class is the one chiefly in use. There is a great variety of exhausting fans, each of the respective inventors of which claims for his own some particular merit. It is not intended here to recommend any special fan, but to give general information on the work produced by some of the mechanical ventilators. As to the kind of fan to be adopted at a colliery, there are two points to be considered, the cost of erection and the probable useful effect it will produce. According to the reports of various experimenters, the useful effect of different fans has been ascertained to vary as much

as from 30 to 80 per cent. of the power applied. In England, both the Guibal and the Waddle have been favorite fans for a long time, but of late, quick-running ventilators, such as the Capell and Chandler, are being very much adopted.

25. The high-speed Capell fan has recently become extensively used in English and German collieries, and the following details are given of some of the work it has done:

TABULATED RESULTS OF EXPERIMENTS WITH CAPELL FAN.

Colliery where Ventilator is at Work.	Diameter and Width of Ventilator.	Size of Engine.	Revolutions of Fan.	Volume of air in cubic feet per minute.	Water-Gauge.	Useful effect per cent.
		ins.				
Waleswood ...	10′0″x8′6″	24 x 36	210	108,700	3·1	82·0
East Howle ...	12′0″x10′0″	20 x 36	200	156,510	3·3	71·6
Shirland	12′6″x5′8″	18 x 24	212	123,200	3·85	71·0
White Lea	8′0″x4′0″	12 x 25	288	56,814	2·5	78·27
Ioachin Essen .	8′0″x5′6″		333	66,500	4·7	73·9

With respect to this fan it is stated that at the Prosper No. 1 Colliery, Borbeck, Westphalia, it exhausted 126,480 cubic feet of air per minute with a water-gauge of 10·7 inches, this is the highest water-gauge the writer has known a fan to be worked at. The results given in this table of the work done by the fan at Waleswood are from experiments made by the writer.

26. A large number of Guibal fans have been erected at the coal mines of America, England and on the Continent of Europe. Being a fan of large capacity, it does not require to run at so great a velocity as some of the other fans to exhaust the same volume of air. Makers of this fan some time back issued the following table to represent practically the duty of the various dimensions at a fair working speed. This, however, varies naturally with the condition of the shafts and air-ways of the mines, sometimes exceeding the tabulated figures in cases of large air-passages, and at other times falling short of them where the currents are hindered by heavy frictional resistance.

Diameter of Ventilator.	Width of Ventilator.	Volume of Air per minute.	In Cubic Feet.	Water-Gauge in Inches.	Suitable Size of Engine.	
					Diameter of Cylinder.	Length of Stroke.
ft.	ft.			ins.	ins.	ins.
10	4	20	000	0·50	6	12
12	4	30	000	0·65	12	12
16	5½	40	000	0·80	12	18
20	6½	50	000	1·20	18	18
24	8	70	000	2·00	20	20
30	10	100	000	2·75	24	24
36	12	150	000	3·50	30	33
40	12	200	000	4·25	36	36

27. The Waddle fan has deservedly a good reputation, and is comparatively cheap in erection; it will exhaust a large volume of air, but runs at a higher speed than the Guibal. The following particulars show the results of observations made on the working of one of these fans, 35 feet diameter, at Holmside Colliery, Chester-le-Street, County of Durham, England.

Revolutions of Fan per minute.	Volume of Air in Cubic feet per minute.	Water-Gauge in inches.	Efficiency per cent.
29·60	83,742	·777	66·7
37·20	108,777	1·082	66·9
50·	140,158	2·07	65·3

As it is a rule in ventilation that the quantity of air in motion is in accordance with the square root of the pressure, or the water-gauge, we may apply it to the above results, thus :

The square root of ·777 = ·881
The square root of 1·082 = 1·04
The square root of 2·07 = 1·439

then if ·881 : 83742 :: 1·04 ought to give 98,853, and 1.439 ought to give 136,782, which figures are different from the actual quantities given, but the discrepancies might be occasioned by

the reading of the water-gauge in the first quantity being put a little too high. Although here the quantities do not come out mathematically true, the law of ventilation mentioned is practically maintained.

28. The quantity of air passing in a mine is in accordance with the square root of the pressure in force.

The pressure of the ventilation is according to the square of the quantity of air passing.

The power is according to the cube of the velocity.

The quantity is according to the cube root of the power.

The volume of air exhausted by a fan is in proportion to the speed at which it runs.

The water-gauge or pressure is in proportion to the square of the speed at which a fan runs.

The power applied to the axle of a fan is in proportion to the cube of the speed at which it runs.

In furnace ventilation, if the same difference of temperature be maintained in the down and upcast shafts, the ventilating pressure will be according to the depth ; therefore the quantity of air to be obtained by furnace will be sensibly proportionate to the square root of the depth.

29. Doubling the velocity of air in roads, without altering their dimensions, increases the pressure fourfold, and the power eightfold ; the pressure being according to the square and the power according to the cube of the velocity. If the velocity be increased from 4 to 5 feet per second the relative pressures will be in the proportion of 16 to 25, and the powers as 64 to 125, because $4^2 = 16$, $5^2 = 25$, and $4^3 = 64$, $5^3 = 125$.

30. The power necessary for overcoming the friction of air in roads increases as the area of the roads diminishes ; thus, thirty-two times the power is required to pass the same quantity of air through a road 3 feet square, as one 6 feet square ; this is carefully worked out in the following table :

Size of air-ways.	o.	a.	$o\left[\frac{1}{a}\right]^3$,	Relative powers, making the road. $6 \times 6 = 1$.
6×6	24	36	·0005144	1·
5×5	20	25	·0012800	2·29
4×4	16	16	·0039062	7·59
3×3	12	9	·0164608	32·
2×2	8	4	·1250000	243·

From this it will be seen that it is not only difficult to get the same quantity of air through small air-ways as larger ones, but practically impossible to do so.

31. The power necessary for overcoming the friction in round

shafts increases as the diameter diminishes in an almost incredible ratio; in a 14 foot shaft three and a half times as much power would be used up in friction as would be necessary in an 18 foot shaft. In fact the power required for overcoming the friction of the same quantity of air increases in inverse ratio to the fifth power of the diameters of round shafts or airways.

32. It will be seen that the ventilation of a mine is much more easily promoted where the shafts and underground roads are roomy, than otherwise—the resistance being greatly increased by the reduction in the size of the air passages—the resistance being in inverse proportion to the square of the area, thus a road 16 feet area, will require four times the ventilation pressure to pass the same quantity of air as one 32 feet area.

33. When the underground workings are extensive, each district should be ventilated by a separate split or current of air, and the foul air of each district conveyed to the main return, without passing through the workings of another district. Splitting the air, is to divide the current into two or more currents by allowing it to pass along from one into two or more roads. This is equal in effect to increasing the area of the original road, and reducing the velocity and consequent resistance of the air current. By this means, likewise, a current of fresh air is taken into each district, which is thus ventilated separately from the rest of the mine, so that in case of an explosion of fire-damp in another district, it has a chance of being isolated from the effects of it.

By Section 7 of Article X of the Anthracite Mine Law of 1891, "Every mine employing more than 75 persons, must be divided into two or more districts. Each district shall be provided with a separate split of pure air, and the ventilation shall be so arranged that not more than 75 persons shall be employed at the same time in any one current or split of air." And Article IV., Sec. 2 of the Bituminous Mine Law of Penna., 1893, provides that:

"After May thirtieth, one thousand eight hundred and ninety-four, not more than sixty-five (65) persons shall be permitted to work in the same air-current. *Provided*, That a larger number not exceeding one hundred may be allowed by the mine inspector when, in his judgment, it is impracticable to comply with the foregoing requirement, and mines where more than ten (10) persons are employed shall be provided with a fan, furnace or other artificial means to produce the ventilation, and all stoppings between main intake and return air-ways hereinafter built or replaced, shall be substantially built with suitable material which shall be approved by the inspector of the district."

34. The equal splitting of air, is a matter that cannot practically be carried out; it can only be done when all the splits leave the main intake current at the same place, and join the

main return together; they must likewise have equal length, area and rubbing surface, so as to offer an equal amount of resistance.

If a number of splits leave the main air-current at the same place, they will all be subject to the same pressure, but if they are of unequal length and area, the friction in each division will be different, and consquently the quantity of air passing in each current will be different. If a split be made at the pit bottom, the air of that split will have a greater pressure than a split made further in towards the workings. Of course, the quantity of air in a short split may be reduced by putting in a regulator. The quantity of air passing in different splits cannot but vary, unless they are equalized by regulators, because by the nature of mining, they are sure to be of different lengths and areas, are not always split at the same place, and consequently not subject to the same amount of pressure—the pressure decreasing as we move along the current in going towards the workings.

35. The pressure on a door or stopping erected between the intake and return may be ascertained by inserting a water-gauge through a hole; the difference of the height of the water in the two legs of the tube represents the pressure. Supposing the two long roads on Fig. 2 represent the intake and return of a mine and that they are each six feet square, and that the short roads between them are 500 yards apart, and that the current is moving at a velocity of five feet per second, it will be found by calculation, taking the co-efficient at ·00000001 pound per square foot of rubbing surface for a velocity of one foot per minute, that the water-gauge will read at the stoppings in the short roads between the intake and return as follows:

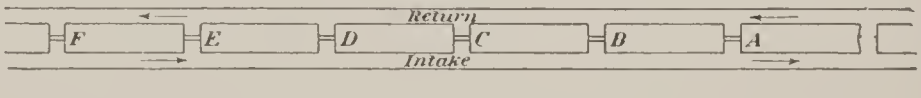

Fig. 2.

At A	·35 inches of water-gauge.
At B	·69 inches of water-gauge.
At C	1·04 inches of water-gauge.
At D	1·38 inches of water-gauge.
At E	1·73 inches of water-gauge.
At F	2·08 inches of water-gauge.

36. A fair velocity for air to travel at in a mine where men are working, in an ordinary sized road, is about 4 or 5 feet per second. Air should not be split so as to reduce the current below a speed of say 3 feet per second.

37. Although under paragraph 77 of the *Theory and Practice of Ventilating Coal Mines*, the writer has recommended

that air, in ventilating single places, should be taken in by the narrow side, he certainly thinks it will be much more pleasant, both in sinking pits or driving tunnels, where there is plenty of ventilating pressure, that the air be taken down or along the large side. By this means the workmen can always get to their work by passing down or along the intake or fresh air side, and the powder smoke or other foul air will pass away on the narrow side, and by this plan there is a great advantage in having the air in the shaft or tunnel clear so that the workmen can have a good sight of all around them.

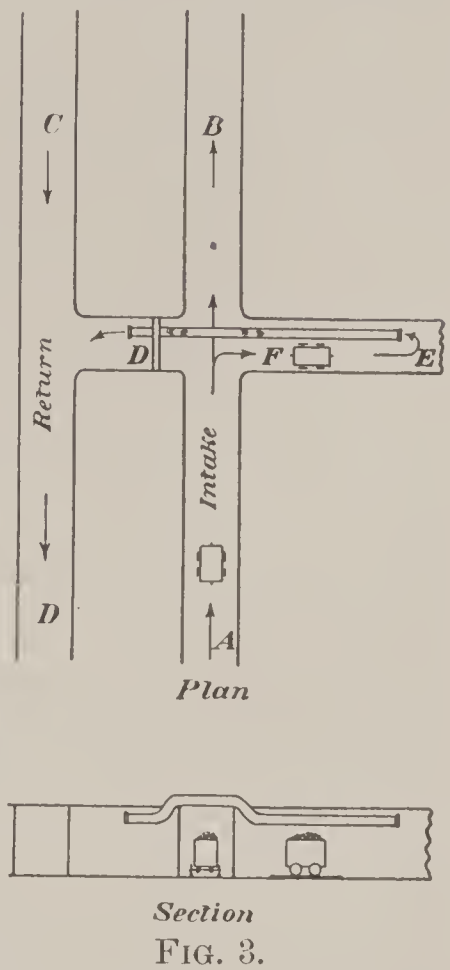

FIG. 3.

38. On the question as to which should be the intake, the broad or narrow side, a German miner, the author of *Schlagwetter*, says: "Where single places are ventilated by air tubes, those through which the air is blown in should have the preference, because the air in the small tubes has a greater velocity and consequently is more efficacious in diffusing the gas. A government inspector in Saxony, Bergamtsrath Menzel, made several experiments at Brackenberg, No. 2 shaft, Zwickau, by using air tubes, and at different times passing the air in and out of them, and found the quantity of fire-damp two to three times as great when the air was drawn out of the tubes as when it was forced in."

The opinion of the German authority is here quoted for the benefit of the student and practical man, but notwithstanding it, and the opinion previously given by the writer in his *Theory and Practice of Ventilating Coal Mines*, referred to in the previous paragraph—he is now disposed to say that the fresh air should be taken in the large side of a tunnel if it be used as a traveling road, and for taking out the dirt by a mining car; in very long tunnels or exploring headings he has frequently noticed where the contrary mode was practiced that the powder smoke remained in the road, so that it was not only unpleasant to travel through, but difficult, if not impossible, to put on lines and take sights from them to keep the tunnel straight. Fig. 3 shows how a tunnel, the construction of which is commenced from the intake road, may be ventilated by air-tubes.

39. Gases lying in the goaves or wastes of a mine being

elastic, are much influenced by the alteration of the pressure in the atmosphere.

Practical miners who are at all observant are well acquainted with this fact and notice that the expansion or attenuation of the gas in a goaf will indicate a change in the pressure of the atmosphere before the barometer does at the surface. The barometer is too sluggish in its movements to be of any use as a foreteller of the issue of fire-damp in a mine; gas as an indicator of atmospherical changes is much more sensitive than the ordinary barometer—indeed, it shows the changes of pressure itself more readily than anything else, it being lighter than any other body. Indeed, it has been found by observation that variations in the reading of the barometer do not indicate approaching increase of gas in a mine, the gas being more rapid in its movements than a barometer at the surface, and that the increase of gas in a mine will indicate the approach of a storm many hours before the barometer is moved. (See page 50, Vol. II of Transactions of the Federated Institution of Mining Engineers.) The volume of a gas varies inversely as the pressure upon it, and the density and elastic force are directly as the pressure and inversely as the volume. If the atmospheric pressure decreases, the gas contained in a gob, goaf, or other cavity will expand and make its exit into the adjacent roads.

40. Repeated experiments at Karwin have proved in the most convincing manner that by an artificial and rapidly produced rarefaction of the air of the mine, there is a considerable increase in the issue of gas, especially from the gobs or wastes.

41. Roughly speaking, mercury is thirteen and a half times heavier than water, 11,000 times heavier than air, and 20,000 times heavier than fire-damp; it is well for the miner to remember this, as the pressure indicated by a variation of 1 inch of the barometer is represented by a very large body of fire-damp.

42. Blowers or sudden outbursts of gas appear to occur independently of meteorological vicissitudes. In order to give those readers who have no knowledge of blowers an idea of what those outbursts are, the following paragraph is quoted from the Final Report of the Royal Commission on Accidents in Mines (Great Britain), page 23: "Numerous sudden outbursts have been described, especially those at the colleries of Walker, Jarrow, Haswell and Hebburn, in which the eruption of gas was accompanied by the dislodgment of large quantities of coal, much of it in a disintegrated state (known as 'dantywal'). The clear description by Mr. G. Clark of two such cases which occurred in November and December, 1846, from the low main coal at Walker Colliery records that in approaching a slip dike a quantity of small coal amounting in one case to eleven tons was violently projected into the workings, accompanied by a discharge of gas, which in the course of a few minutes fouled, respectively, 41,000 cubic feet and 86,000 cubic feet of the air pas-

sages. So good, however, was the discipline, and so prudent the behavior of those present, that although a terrible explosion seemed imminent and several of the Davy lamps became red hot, no accident happened."

43. It is believed that there is some connection between earthquakes, the issue of gas in coal mines, and the occurrence of colliery explosions. Dr. Rudolph Falb, a German Philosopher, holds this opinion : "His theory is that the inner portion of the earth must be regarded as liquid, and that the fluid of the interior is drawn by the attraction of the sun and moon into the cracks and channels of the earth's crust ; when cooling takes place, explosions of gas occur, and subterranean volcanoes become extinct."

44. Professor Milne, the author of *Earthquakes and other Earth Movements*, does not believe that the changes of the barometer have any marked connection with the occurrence of earthquakes in Japan at least, where so many of these terrible occurrences take place. He says, however, that the phenomena of the emission of steam from Stromboli and noises from the volcano of Vulture, occurring as they do on certain changes of the weather, have a direct relationship to barometrical pressure.

45. Blasting with gunpowder in dry and dusty mines may cause serious disasters in the entire absence of fire-damp, and there is no doubt that the presence of fine coal dust in a mine very much exaggerates the force of an explosion ; indeed, it is said that all dust, not only the dust of pure coal, is more or less dangerous.

45½. Before a shot is fired, a careful search should be made to ascertain whether fire-damp is present or not. The operation should not be carried out where the ventilation is not sufficient to render the gas harmless. In fiery mines, and those which have much coal dust, the practice of shot firing should be limited as much as possible or prohibited altogether. By Rule 63 of An Act relating to the Bituminous Coal Mines of Penna., approved May 15th, 1893, it is provided that : "When a workman is about to fire a blast he shall be careful to notify all persons who might be endangered thereby and shall give sufficient alarm so that any person or persons approaching shall be warned of the danger."

46. Return air as a rule is lighter than intake air ; on this account it is better where practicable to take return air upwards rather than otherwise. In the coal mines of Westphalia where the seams frequently lie at a steep angle, as shown in Fig. 4, the usual way is to carry the air in the first place to the lowest working level of the colliery and pass it up to the upper levels, and eventually to the return airway—the air being conducted ascensionally through the mine. By this mode the ventilation pressure is increased, without the expense of applying artificial means, but simply by utilizing this natural law, so that where

the temperature of the intake is 50° and the return is 95° an additional pressure of over 5 lbs. per square foot is obtained—nearly equal to one inch of water gauge—where the rise workings are 800 feet above those of the deep.

FIG. 4.

47. Shallow pits are more difficult to ventilate than deep ones, because with them you cannot get so great a ventilating pressure as by deep shafts.

48. The ventilation of deep mines is less affected by changes of the weather than that of shallow ones; as the mine increases in depth so does the temperature, and consequently the ventilating pressure.

49. In England it has been noticed that a south wind is unfavorable to the ventilation of shallow mines; on the contrary a north wind is favorable.

50. Changes of the weather do not materially affect the circulation of air in any mine where proper artificial means of ventilation are provided.

51. Dip workings in a mine are more easily ventilated than rise places.

52. Air always takes the short-cut when under pressure, and without pressure there will be no current.

53. Narrow places, especially in fiery mines, should not be driven in advance of the air current.

54. Good ventilation and a good light will tend much to the safety of all engaged in mining operations.

55. Notwithstanding the law of diffusion of gases, it is generally found, that the lighter gases remain in the upper part, and the heavier gases in the lower part of a mine. There is great difficulty in mixing atmospheric air with inflammable gas.

56. Walling back gas, should not be practiced; when a disused road is abandoned it is better to fill it up altogether, or pass a current of air through it; many explosions have occurred by stoppings and dams in such cases having proved imperfect, through which the gas has escaped and come onto naked lights. According to Art. V., Sec. 1., of An Act relating to the Bituminous Coal Mines of Penna., the law is that: "All mines generating fire-damp shall be kept free of standing gas in all working places and roadways. No accumulation of explosive gas shall be allowed to exist in the worked out or abandoned parts of any mine, when it is practicable to remove it, and the entrance or entrances to said worked out or abandoned places, shall be properly fenced off, and cautionary notices shall be posted upon said fencing, to warn persons of danger."

57. Stoppings put in rise places, should be placed at or near the lower end, next to the intake current; this prevents an accumulation of gas on the lower side of the stoppings, which might come in contact with naked lights, which are generally used in the intake.

58. The best safety lamps afford no protection when handled imprudently, and there are many conditions when some of the so-called "safety lamps" are dangerous, particularly the Clanny and Davy, which have been exploded in an inflammable mixture passing at the rate of 8 feet per second. By Art. V., Sec. 6, of the Act relating to the Bituminous Coal Mines of Penna.: "The use of the common Davy safety lamp, for general work in any Bituminous coal mines, is hereby prohibited, neither shall the Clanny lamp be so used, unless its gauze is thoroughly protected by a metallic shield, but this Act does not prohibit the use of the Davy and Clanny lamps by the mine officials for the purpose of examining the workings for gas."

59. Workmen should not be allowed to ramble about a mine from one place to another. General Rule 71, of the Bituminous Coal Mines Act of Penna., approved May 15, 1893, provides that: "No person or persons shall go into any old or abandoned parts of the mine, or into any other place which is not in actual course of working, without permission from the mine foreman, nor shall they travel to and from their work except by the traveling way assigned for that purpose."

60. Wafting or brushing gas away should not be allowed—the gas should be removed by a current of air. According to General Rule 66, of the Bituminous Coal Mines Act of Penna.: "An accumulation of gas in mines, shall not be removed by brushing."

61. It is the opinion of the writer, in which he is supported by many mining authorities, that mixed lights should not be used in a mine—that is to say, safety lamps in one part and candles or other naked lights in another part.

62. In all cases of an explosion, it is a good plan, if a man

has sufficient notice, to throw himself upon his face until the blast passes over him, and as soon as he is satisfied that it is over (it is frequently repeated at the interval of a minute or two) let him calm his fears as much as possible, and make his way out toward the fresh air. This was a recommendation of the late Mr. Matthias Dunn, one of the original inspectors of mines in England.

63. In all cases where fire-damp accumulates, it is important that no attempt should be made by the workmen to remove it, except under the direction of some responsible person; care being taken that the foul current in passing along the return side towards the upcast, shall not endanger the lives of any workman who may be engaged there.

64. Special care should be taken for fear of an accumulation of gas when the pit commences work, after Sundays or holidays. This admonition is made because accidents have frequently happened through the ventilation having become disarranged during the suspension of coal working. From this we might expect Monday to be the most dangerous day of the week as regards explosions of gas, and since making this note the writer has been confirmed in that view by the publication of the report of the Prussian Fire-Damp Commission, from which it appears that of 1,666 explosions which occurred, they took place, according to the days of the week, as follows:

Sunday	44
Monday	327
Tuesday	273
Wednesday	240
Thursday	271
Friday	259
Saturday	252

65. Ventilation plans showing, by arrows, the course of the air currents, and by a variation in color the different splits, should be kept regularly up to date. By Art. I., Sec. 1, of the Bituminous Coal Mines Act of Penna., the map or plan of a coal mine shall show "By darts or arrows made thereon by a pen or pencil the direction of air currents in the said mine."

66. In Great Britain, the lives lost by explosions of fire-damp form 21 per cent. of the total number lost at collieries; the number lost by falls of roof and sides is 40 per cent. and by miscellaneous accidents 39 per cent. over a series of years. In the Anthracite Coal Mines of Pennsylvania in 1891, the percentages of accidents were as follows:

Explosions of gas	8·88
Falls of roof and coal	39·72
Miscellaneous	51·40
	100·00

In the Bituminous Mines the percentages work out as follows :

Explosions of gas	50·00
Falls of roof and coal	31·98
Miscellaneous	18·02
	100·00

67. There are a number of different gaseous mixtures that are, under certain conditions, explosive—for example, light carbureted hydrogen, olefiant gas, coal gas, carbonic oxide, sulphureted hydrogen, some sewer gases and other emanations; and there appears to be no doubt that dust of flour will also explode under particular circumstances. A flour dust explosion occurred on the 21st of March, 1893, at the Keeler flour mill, Litchfield, Ill., when the immense structure was blown to fragments. The nature and composition of the explosive gases given off in mines vary very much. Fire-damp is very often written about and spoken of as being pure carbureted hydrogen, whereas it is often mixed in varying proportions with other gases. Any gas that will explode may be considered fire-damp. In the practical working of mines, and by experiment, it has been found that dry atmospheric air with an admixture of coal dust is explosive, and by General Rule 60 of the Bituminous Coal Mines Act of Penna., it is provided that "In mines where coal dust has accumulated to a dangerous extent, care shall be exercised to prevent said dust from floating in the atmosphere by sprinkling it with water or otherwise as far as practicable."

68. Miners may be suffocated by going into fire-damp by the inhalation of the gas, without an explosion taking place. In the evidence given before the Royal Commission on Accidents in the Mines of Great Britain by Mr. Dickenson, he said that people were occasionally suffocated by fire-damp, and further on that "fire-damp can suffocate as well as black-damp if you have it strong enough."

69. Carbonic acid gas, or carbon dioxide ($C O_2$) is often met with in coal mines—particularly shallow mines; its chemical composition by weight is oxygen 72·73 per cent., carbon 27·27; its specific gravity as compared with air is 1·525—it is poisonous, and is dangerous to breathe when it is contained in the air to the extent of 8 per cent., and lights will not burn in air containing 10 per cent of it. When lights are extinguished by it, it is a warning that the air is contaminated with it to such an extent as to render it highly dangerous to breathe. It is given off by the respiration of animals, combustion, fermentation, decay of vegetable matter and volcanic emanations.

70. Carbonic oxide, or carbon monoxide (C O) is composed by weight of 56·69 per cent. of oxygen, and 43·31 of carbon, and its specific gravity is ·975, air being 1. This gas has a far more deleterious effect on the animal system than carbonic acid; for

if atmospheric air be mixed with 1 per cent. of it, the breathing of it is fatal, whilst, at the same time, a lamp will burn in it. It is found where gob fires exist, and is the result of incomplete combustion. It is inflammable, and as the late Mr. Henry Johnson stated in his evidence before the Royal Commission on Accidents in the Mines of Great Britain—"explosions from spontaneous combustion are due to a certain admixture of atmospheric air with carbonic oxide." It is a colorless, invisible gas, without taste or smell, and burns with a bright blue flame.

71. Carbureted hydrogen or methyl hydride ($C H_4$) has a specific gravity of ·555, and is composed of 24·6 per cent. by weight, of hydrogen, and 75·4 per cent. of carbon. It is highly explosive when mixed with certain proportions of air; when present to the extent of one part to thirty parts of air, by volume, it may be detected by the flame of a candle, and 4 per cent. will show a blue cap on the flame of a safety lamp. It has hitherto been considered that 7 to 14 per cent. of this gas mixed with air is the maximum of explosibility, but probably a very much smaller percentage is sufficient to cause an explosion in some mines. The carbureted hydrogen of mines is found to be mixed with various proportions of other gases, and that of one mine is frequently very different from that of another mine.

72. Olefiant gas, called likewise heavy carbureted hydrogen, or ethylene, has the chemical symbol C_2H_4, and a specific gravity of ·9784. It is composed of 2 atoms of carbon and 4 atoms of hydrogen, and is produced by the distillation of coal and carbonaceous matter. It is a colorless, invisible gas, possessing a sweetish taste, and burns with a brighter flame than marsh gas.

73. Sulphureted hydrogen, or hydric sulphide, known by the symbol $H_2 S$, is composed by weight of 94·15 per cent. of sulphur and 5·85 per cent. of hydrogen. Its specific gravity is 1·19, air being 1.

It is a colorless gas having a smell, by which its presence is easily detected, of rotten eggs. It is inflammable, and burns with a pale bluish flame. It is met with in coal mines, and is evolved from volcanoes. It occurs also in solution in many mineral springs, such as those of Harrowgate in Yorkshire, England.

74. Sulphurous acid gas has been found in the air of Cornish mines and elsewhere; it is one of the products of blasting. It is frequently found in the water, which occasionally contains sulphuric acid, as is the case in some furnace shafts.

75. An explosion of fire-damp renders ten times its bulk of air unfit for respiration, and this vitiated atmosphere, called after-damp, is very deleterious and causes more loss of life than the explosion itself. An explosion destroys the oxygen in the air and produces carbonic acid, carbonic oxide, steam and nitrogen, all of which are unbreathable.

It has been calculated that an explosion of carbureted hydrogen and air will exert a pressure of 210 lbs. on the square inch, which is equal to 162 tons on the square foot, but by experiment it is found that the extent of its effects on the workings of a mine depends very much on where the gas is fired.

76. Gob fires or spontaneous combustion of coal in goaves take place through leaving large accumulations of slack, or small coal, in the mine, and they are more frequent in thick than in thin coal seams. The thicker the coal lies on the floor, and the damper it is, the quicker it fires. The primary cause of gob fires in the Dudley, England, thick coal is not attributed to the presence and oxidation of iron pyrites, but it is considered that spontaneous combustion takes place through the action of oxygen upon the finely divided coal. The seam of coal in South Staffordshire, England, which contains the largest quantity of iron pyrites—namely the stinking coal, is not liable to spontaneous combustion. Mr. Henry Johnson said before the Royal Commission on Accidents in Mines in Great Britain that "the more impure the coal, the more rapid the spontaneous combustion. A hard, bright coal will produce less gob fire than soft impure rubbishy coal." Gob fires, which are almost unknown in the deep coal, have frequently taken place, in fact, are of common occurrence in the shallow coal of the Cannock Chase district, Staffordshire, and it is a noteworthy fact that more such fires occur during slackness of trade than at other times, more small coal being left in the gob, and the working face not advancing so rapidly then. The reason there are more fires in the "shallow" than the "deep" may be that the shallow is a more volatile coal and likewise contains more dirt. To prevent such fires the slack should not be allowed to accumulate. Gob fires are not known in the Anthracite mines of Great Britain or America.

77. Natural gas exists in the earth in large quantities, under great pressure and at considerable depths. In various parts of England, Scotland and Wales, the gas escaping from the coal measures has at different times been utilized at the surface for the purpose of lighting. The holy fire at Baku in Persia, which has been burning for centuries, is due to the issue of carbureted hydrogen mixed with small quantities of nitrogen, carbon dioxide and petroleum vapors. The gas issuing from the mud volcanoes of Balganek, in the Crimea, according to Professor Bunsen, consists of pure carbureted hydrogen. The largest supply of natural gas hitherto met with is that in the United States of America, in parts of Pennsylvania, Ohio, New York, Illinois, and Indiana, where it is now extensively used for lighting and manufacturing purposes. In Pittsburg, the American Birmingham, natural gas has been used for many years on a large scale for lighting, working and heating. Although natural gas was known in the town of Findlay, Ohio, for a long time—a German physician named Dr. Aesherlin, having lit up

all the rooms of his house with it for thirty years—it was not until 1887 that public interest was aroused in the matter, and bore-holes put down to ascertain the extent of the supply, and the depth and pressure at which it existed. The first hole tapped a feeder of gas amounting to 150,000 cubic feet per day, which when lit up, could be seen at night 15 miles round. Later a deeper hole was bored, which had to pass through a thickness of 350 feet of Trenton limestone; this yielded at a depth of 1,200 ft., 1,206,000 cubic feet of gas per day, but this great yield was exceeded by other holes put down afterwards. At the present time there are over twenty bore-holes in and around Findlay, all of which are yielding large quantities of gas; four of the most fertile in supply yield respectively 12,080,000,—3,318,000,—2,565,000, and 1,159,000 cubic feet daily. The chemical composition of this gas is:

Marsh gas	92·61
Petroleum vapors	·30
Hydrogen	2·08
Oxygen	3·61
Nitrogen	·34
Carbonic acid	·26
Carbonic oxide	·50
Sulphureted hydrogen	·30

One hundred cubic feet of the gas contain 125·8 grains of sulphur. The weight of a cubic foot of gas is 318·98 grains. The average pressure of the Findlay natural gas is 375 lbs. per square inch. The quantity of natural gas which issues from bore-holes, appears to diminish, and the pressure gets less as time goes on. According to a recent report of the Indiana State Geologist, the pressure of the gas in the Indiana field was at first 325 pounds to the square inch, but it has in some cases decreased to 60 pounds. Many of the holes are entirely useless, some because the gas supply is exhausted, and others on account of the presence of salt water. The field in the immediate neighborhood of Kokmo is entirely exhausted. The greatest pressure in the Anderson Field is 325 pounds. The State Geologist of Illinois, in referring to the natural gas deposited there, gives it as his opinion that it did not originate in the olden formations of the Devonian and Silurian, from which the main supply of this material is obtained in Ohio and Pennsylvania, but had been generated in one of the old peaty soils, which are interstratified with the drift clays, and are found intact over extensive areas in Illinois.

78. The issue of natural gas has in more than one instance been the means of setting a river on fire. A small river known as Catfish Run, in the petroleum regions of Pennsylvania, has for years been covered with bubbles. These, on bursting, emit a strong smell of gas. On one occasion some visitors to the neighborhood, by way of experiment, saturated a bunch of

rags with oil, set fire to it, and allowed it to float down the stream. The flame ignited the gas, and an explosion followed. In a few moments the body of the gas burned steadily, and from every portion of the surface of the water small flames sprang up, when the gas escaped in moderate quantities. It is said the gas has continued to burn ever since, and at night the effect is magnificent. A similar phenomenon has been witnessed on the River Wear at Framwellgate, near Durham, where fire-damp issuing from the coal mines has been seen to burn for some time.

CHAPTER II.

EXPLANATION OF TERMS USED IN THE SUBJECT OF MINE VENTILATION.

Aerophore.—The name given to an apparatus which will enable a man to enter places in mines filled with explosive or other deadly gases, work there with freedom, take with him a light, and remain for an indefinite time. (W. S. Gresley.)

After-damp.—A noxious mixture of gases resulting from an explosion of fire-damp. It has always been impossible to make an exact analysis of the after-damp from an actual explosion, but one result of it is to use up the oxygen of the air and to produce carbonic acid and steam, as well as sometimes carbonic oxide, which with the nitrogen, make the mixture unbreathable. Carbonic oxide or carbon monoxide is not usually present in after-damp, but from certain explosions, in which coal-dust has formed part of the combustible material, it has been found to exist.

Air-course.—A road constructed and kept open for the air to pass along.

Air-crossing.—A place in the mine where one current of air passes over another; such a crossing is often made by building walls on each side of the lower road, and laying planks across from one side to the other; it is sometimes formed by arching with masonry, by iron tubes, or otherwise; or it may be made by driving in the solid rock one road over or under the other.

Air-pipes.—Tubes or boxes for air to pass through to ventilate a single underground road.

Air-troughs.—The same or similar to air-pipes; they are made of different materials, wood, iron, earthenware, or canvas; when made of the latter material, they are kept open by iron hoops being placed inside at intervals.

Anemometer.—An instrument used to ascertain the speed at which air flows through a mine, which may easily be read on the face of the instrument. It is liable to get out of order through coal dust and damp, and should occasionally be tested

and rectified. The quantity of air passing per minute in an air road may be ascertained in this way: Measure the size of the road, and read off the number of revolutions made by the anemometer in a given time, say a minute, then multiply the area of the road in feet by the speed, this will give the cubic feet of air passing per minute. If the velocity of the air be 400 feet per minute, and the road measures 8 feet by 6 feet, then the quantity of air passing per minute will be 19,200 cubic feet.

Area.—The superficial measure of anything, as for instance the section of an air-passage, which is obtained by multiplying the height by the width. If a road measures 7 feet high and 9 feet wide, then its area is $7 \times 9 = 63$ sq. ft.

Artificial Ventilation.—The means put in force to produce a current of air. The way this is done is by altering the density of one end of the air-current. For this purpose sometimes the furnace is used and sometimes the fan. By the action of the furnace the air, at the outlet end of the column, is heated and consequently made lighter or more attenuated, towards which the colder air, at the other end of the column, flows. By the action of the exhausting fan, a vacuum is formed, into which the air from the mine passes so long as the machine is kept in motion.

Ascensional Ventilation.—The principle of coursing the air, after it has descended or entered the mine, through the workings in an upward direction. Mine air being usually lighter than the outer air, will naturally tend upwards. To carry the principle out fully, the upcast shaft should be placed on the rise or crop side of the workings. Of course, in flat-lying seams the principle does not apply.

Asphyxia.—This is a word used by members of the medical profession, and is frequently found in the reports of mine inspectors. It signifies a lowering of the pulsation, but is generally used to mean a total cessation in respiration, caused by the prevention of the entrance of pure air to the lungs. This condition of the human body is caused by inhaling after-damp and other mixtures of noxious gases; asphyxia will result from the breathing of carbonic oxide, carbonic acid and, in some cases, fire-damp.

Atmosphere.—The air which surrounds this spheroidal earth of ours, and which is composed of a mechanical mixture of oxygen, about one-fifth; and nitrogen about four-fifths. Several properties of the atmosphere are described under paragraphs 1 to 11, in Chapter I.

Bag.—As referring to fire-damp, it means a small quantity of gas given off from a coal-seam, or a small quantity lying up in a hole in the roof.

Barometer.—An instrument used for measuring the pressure of the atmosphere. It is constructed in various forms, but the best and most practical is a straight tube of glass sealed at one

end so as to be quite air-tight; when this is filled with mercury the open end is closed with the thumb, and it is inverted into a cup of mercury. The mercury in the tube will then descend until its weight just balances the pressure of the atmosphere. The upper surface of the mercury will rise and fall according as the pressure of the air varies, and this is measured by a scale. The barometer may be used for finding depths of shafts—near datum of sea level—by the following rule:

$$D = \frac{26216 \times I}{B}, \text{ and}$$

$$I = \frac{D \times B}{26216} = \text{difference of reading of barometer at top and bottom of shaft,}$$

where I = inches of mercury due to depth of shaft,
D = depth of shaft in feet,
B = height of barometer at pit top.

Barometer Holiday.—A term used in Derbyshire to signify an idle day at the mines, occasioned by the barometer being low—perhaps down to 29 inches and which affects the ventilation by causing an accumulation of gas.

Black-Damp.—The name given to carbonic acid gas when found in a mine. It is a very heavy deadly gas, and when a candle is put into it the light goes out and the wick is left quite black—hence probably the name.

Blower.—A sudden eruption of fire-damp into the workings of a coal mine. Unexpected issues of explosive gas have frequently taken place in deep coal mines of different coal fields, and considering the immense pressure at which gas is contained in the coal-seams, it cannot be argued that they are due to a reduction in the atmospheric pressure. They often occur in working-faces, and sometimes with such force as to baffle the ventilation and put the mine in a very dangerous condition. When this is the case a current of air in sufficient quantity to dilute the gas should be passed through the place where the gas issues, in order to render it harmless, and the workmen should be withdrawn on the return side of the issue. Although it may be said that in most cases the gaseous mixtures coming off at blowers are made up chiefly of methane or carbureted hydrogen, they are frequently composed of varying proportions of air and the several kinds of gases. Sometimes the issue is chiefly carbonic acid, and at other times it is chiefly oxygen and nitrogen.

Blower likewise signifies a fan used for forcing air into a mine.

Blow George.—The name given in Somersetshire, England, to a small mechanical blower or ventilator used for blowing air into single roads underground.

Blow-out.—A blast throwing out the tamping without bringing down the rock or coal.

Blown-out-shot.—This word is commonly used in England to signify the same thing as the word "Blow-out" does in America.

Boyle and Mariotte's Law.—The law relating to the dilatation of gases, which is this: The volume occupied by a gas is in inverse ratio to the pressure under which it exists, if the temperature remains the same, or the density of a gas is proportional to its pressure, so that air under the pressure of three atmospheres will occupy only one-third the space it occupied under the pressure of one atmosphere. If the temperature be increased, and the air occupy the same space, the pressure will be increased, but if the pressure remains the same, the air will occupy a larger space.

This property of the expansion of air explains the phenomenon of bursting a bladder by holding it by the fire; the internal space of the bladder being limited, the pressure of the air increases with the temperature until the limited strength of the bladder can no longer resist it and an explosion occurs. Air may be compressed so as to occupy only one-thousandth part of its original space, or it may be so much expanded as to fill two thousand times the area of the original volume. The co-efficient of expansion, or increase in the volume of air for each additional degree of heat on the Fahrenheit scale, is equal to ·002039.

Break-through.—An opening through a pillar for the passage of air.

Breather.—An apparatus constructed to enable a man to breathe in impure air. It consists of a reservoir charged with oxygen gas, fitted up with a mouth-piece and tube.

Breeding-fire.—Same as Gob fire.

Brush.—To dash away a body of gas with a cloth, such as a jacket or waistcoat; but to remove gas in this way is against the law, as is mentioned in par. 60, Chap. I.

Cap.—The halo on the top of a flame. Fifty years ago, and prior to that time, it was a very common thing for the overmen and deputies of the North of England mines to try the candle for gas, by first snuffing the wick and lowering the flame as much as possible, and then placing the hand before it, and gradually raising it to see if it showed any cap. The cap or halo formed on the top of a light by carbureted hydrogen is blue, and by this means it used to be detected. In examining a mine, or in trying or searching for fire-damp, a naked light should not be used, but a safety-lamp.

Carbonyl sulphide.—(C O S). A dangerous compound, which is easily inflammable. It is supposed that this gas was present in a sample from a blower at Friedenshoffnung Colliery, in Germany.

Centigrade.—The word means to be divided into hundredths.

The term is applied amongst other things to the thermometer, when the distance on the scale between the freezing point and boiling point is divided into one hundred equal parts. This is the scale mostly used for thermometers on the Continent. (See Thermometer.)

Clanny.—The name given to the safety-lamp designed by Dr. Clanny of Newcastle-on-Tyne. He altered the construction of the Davy, by replacing part of the gauze with glass, by which a better light was obtained. With many it is a favorite lamp as now constructed in its improved form.

Co-efficient of friction.—The quantity or number used as a multiplier representing the pressure for overcoming the friction of air, at a given velocity, in rubbing against a given area of surface of an underground channel, in passing along it. For a velocity in the air of 1000 feet per minute, the friction may be taken to be equal to ·12387 feet of air column of the same density as the flowing air, which is equal to a pressure of 0·01 per square foot of area of section. There are various estimates of the value of this factor. M. Murgue in his recent exhaustive experiments on the friction of air in mines, conducted with great care, and during which the most delicate possible tests were made, found that in

(1) Brick-lined arched gangways the co-efficient was ·001743
(2) Unlined rock gangways " " " " ·004965
(3) Timbered gangways " " " " " ·00842

The highest of these being ·00842 makes the co-efficient 0·01 a safe one, and one that makes calculations easy.

Compressed air.—This is sometimes used as a motive power in mines, although it is an expensive one. It has no bearing on ventilation, excepting that the exhaust has the effect of improving the ventilation (in an inappreciable degree in well ventilated mines) and the pipes through which the air passes help to cool the mine.

Coursing of air.—In the earlier days of coal mining, in the coal-field of Northumberland and Durham, before splitting air was practiced, it was usual to take the air through the pillars up two or three boards (or rooms) and down two or three boards; this was called "coursing two and two," and "coursing three and three."

The proper meaning of coursing the air now, is to cause it to move through every space in the mine—especially any place into which a man can travel, or which may be approached by a light—so that noxious gases are removed, and liability to explosions of them, or suffocation from them, prevented. In all cases a provision should be made for carrying the air—or coursing the air—into every advance heading or excavation, whether it be made horizontally, obliquely, or vertically.

In sinking pits from the surface, they are easily ventilated

by connecting the bottom with the chimney of the boiler fires with air pipes.

In the coal mines of Great Britain many accidents have occurred in sinking below working levels, by explosions of gas, in consequence of the air not having been carried down as sinking progresses. This may be done in a very simple manner, as illustrated by the annexed plan and section Fig. 5.

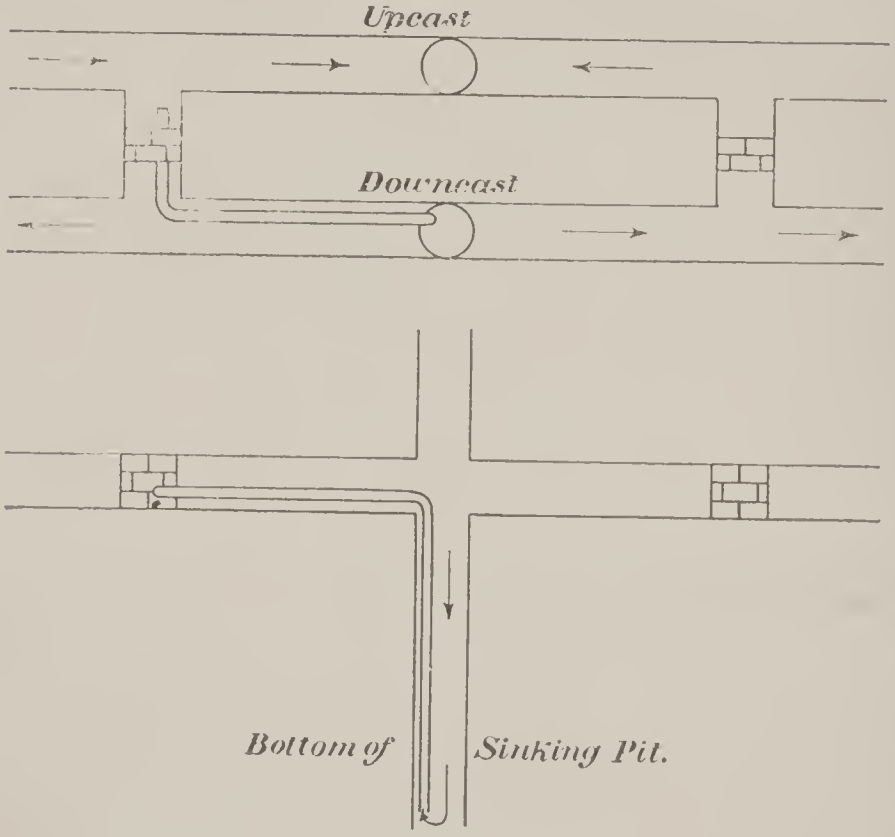

FIG. 5.

All that is required to be done is to pass a line of air-pipes from near the bottom of the shaft to the return air-way as shown in the annexed sketch.

Cube Root.—The common factor of a cube number. Thus 4 is the cube root of 64. A cube number in arithmetic is that which is produced by multiplying a square number by its root. Thus, 8 is a cube number and arises by multiplying 4, the square of 2, by the root 2.

Damp.—Carbonic acid gas. (South Staffordshire.)

Davy.—The name given to the safety lamp invented by Mr. Humphrey Davy, afterwards Sir Humphrey. The "Davy" is an ordinary lamp with the flame enclosed by wire gauze. The explosive gas, when present, passes through the gauze into the cylinder of the lamp and burns inside, giving warning to the miner of its presence, but the flame is unable to pass through the gauze. "These facts depend upon the conducting power of metallic gauze, in virtue of which the heat of the

flame is rapidly dissipated at the points of contact, the result being a diminution of temperature sufficient to prevent ignition."

Dead Air.—The air of a mine is said to be dead or heavy when it contains carbonic acid gas (black-damp), or when the ventilation is sluggish.

Door.—A door erected in a traveling passage to prevent the air going along it. These erections are of different kinds, as:

1. *Flap-Door.*—A man-hole door.

2. *Fly-Door.*—A door erected to open either way, when pushed from either side, but which will always of itself swing to.

The annexed sketch, Fig. 6, shows an example in the application of a fly-door, which the writer remembers was commonly in use over forty years ago, in the coal mines of the

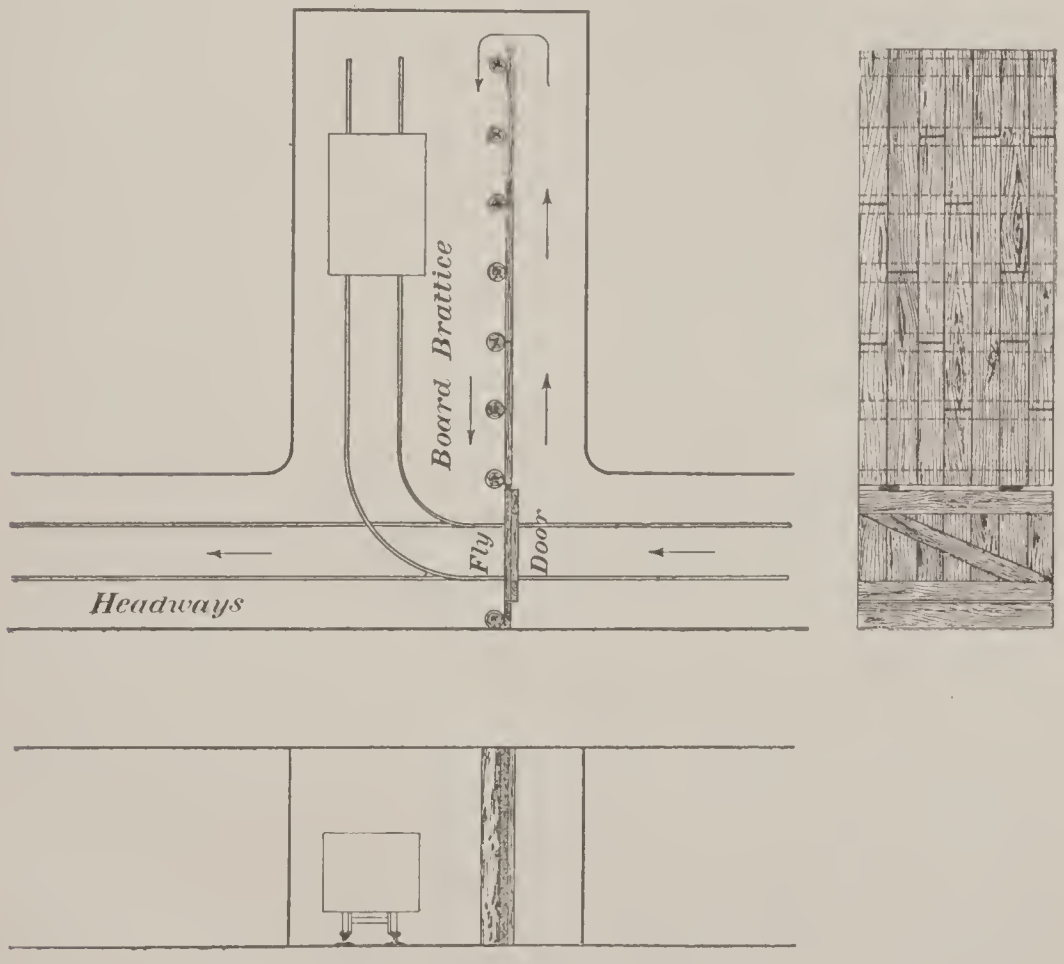

FIG. 6.

northern coal field of England. The door was placed in the *headways*, at each *board-end*—brattice was erected up to the face, and the air flowed in the direction of the arrows.

3. *Sheth-Door.*—A door used for coursing the air backwards

and forwards through old workings of the pillar and stall system of the North of England.

4. *Main-Door.*—A door placed in a proper frame erected for the purpose; it is made to open in one direction—against the current. It is put up in a road to prevent the air going that way, and force it through another district.

5. *Man-Door.*—A door 18 inches or 20 inches square, provided with lock and key, placed in a short road between the intake and return for the repairman or other official to pass through; such doors are usually in pairs, so that when one is open the other is shut.

6. *Separation-Door.*—A main-door put up between the bottoms of the down and upcast shafts; they are frequently in twos and sometimes in threes, a few yards apart, so that in passing through one at a time there is no chance of the air taking the short cut to the upcast.

Downcast.—The name given to the shaft or slope through which the fresh air flows down into the mine.

Drag.—The name given to the resistance met with by the air in passing along the underground channels. The amount of drag or pressure is generally measured by the water-gauge.

Dumb-Drift.—A sloping road made from the return air-course into the upcast shaft which it enters at a sufficient height above the furnace to prevent the air, should it be inflammable, from exploding.

Ethane.—(C_2 H_6). This gas, according to the report of the Prussian Fire-Damp Commission, has been found in a number of blowers. It is likewise said that the gaseous mixtures known as propane (C_3 H_8) and catylene (C_4 H_8) have been detected in coal, and that these two gases may be regarded as produced by the decomposition of marsh gas and ethane.

Equivalent Orifice.—The air in passing through the workings of a mine meets with a certain amount of resistance; this is represented as being equivalent to the air passing through an orifice in a thin plate of such an area that the resistance offered to the entrance of the air would be equal in amount to that offered by the underground workings. In other words the resistance of a mine which requires a certain water-gauge or pressure for the production of a certain volume of air is equivalent to an orifice in a thin plate which requires the same water-gauge to pass the same volume; M. Murgue, the French engineer, assimilates the passages of every mine to an orifice in a thin plate, which he calls the "equivalent orifice."

Fahrenheit.—The name of an eminent philosopher, born at Dantzic, who graduated the thermometer in the manner it is now used in England and America, and which is called by his name. By this scale the freezing point is placed 32 degrees above zero, and the boiling point at 212 degrees. (See Centigrade and Réaumur).

Feeder.—Small stream or blower of gas.

Fifth Power.—The result of a number multiplied five times into itself—thus $2^5 = 32$; and the fifth root of $32 = 2$ and is written thus $\sqrt[5]{32}=2$. A knowledge of these numbers will be of use in calculations with respect to ventilation; for example, the sides of square airways will vary in proportion to the 5th root of their lengths, when the roads are subject to the same pressure and are to pass the same quantities; and the length of the diameters of circular airways will in the same way vary in the proportion of the fifth root of their lengths; and again the power necessary for passing the same quantity of air in square airways of different sizes is in inverse ratio to the 5th power of the sides of the squares, and in circular airways or shafts is according to the inverse ratio of the fifth power of the diameters.

Final Velocity.—The speed at which the air passes out of the upcast shaft, or where there is a mechanical ventilator, the speed of the fan at the tips.

Fire-boss.—A man whose duty it is to examine the workings for accumulations of explosive gas, etc.

Fire-damp.—An explosive gaseous mixture.

Fire-stink.—The name given in the South Staffordshire coal mines to the disagreeable smell arising from decomposed iron pyrites or the products of the spontaneous combustion of coal or other minerals.

Friction.—Same as drag or resistance.

Fugitive Air.—The air which escapes from the intake to the return, without passing through the mine, may be so called. In many cases a large quantity of air enters the mine by the downcast, and escapes from the upcast, then passes around the workings. For example, at F, a mine in the Fifth Bituminous district of Pennsylvania, the mine inspector reports that the air exhausted by the fan is 24,000 cubic feet whilst the quantity in the workings is only 7,600 feet. It does not necessarily follow because there is not so much air in the workings as goes into and returns from the mine by the shaft that the difference is wasted: a part of the air which goes into the mine may very properly be allowed to leave the main current to pass through old or unused workings and make its way to the return without going into the working places; care, however, should be taken that no air is allowed to run away from the intake current unless it be required for the separate ventilation of some place isolated from the working places. Air after having passed through the gob should not pass through the workings, but go direct to the return.

Furnace.—A large fire placed near the bottom of a shaft to reduce the density of the air and and cause a circulation. This appliance for producing ventilation, so well known to miners, is gradually falling into disuse, and therefore a detailed description of it is unnecessary.

Goaf.—The abandoned part of a mine where the coal has been extracted.

Gob.—The same as goaf.

Gob-fire.—A fire which takes place in the gob or goaf, very often spontaneously, from the slack or fine coal left behind. (See par. 76, Chap. I.)

Horse Power.—A term used in mechanical calculations meaning 33,000 lbs. lifted one foot high in a minute. If a weight of 660 lbs. be lifted 100 ft. high in a minute that represents two-horse power. The term is often used in calculations relating to ventilation; for example, if a fan delivers 99,000 cubic feet of air per minute with a pressure of 6 lbs. to the square foot, then the horse-power in the air would be eighteen, because

$$\frac{99{,}000\times 6}{33{,}000}=18.$$

Hygrometer.—An instrument intended for giving precise measurements of the state of the air as regards moisture. Mason's hygrometer has been recommended as better than others for ascertaining the proportion of moisture in the air of mines. It consists of two "similar thermometers, mounted at a short distance from each other, the bulb of one of them being covered with muslin, which is kept moist by means of a cotton wick leading from a vessel of water. The evaporation which takes place from the moistened bulb produces a depression of temperature, so that this thermometer reads lower than the other by an amount which increases with the dryness of the air." Saturated air is lighter than dry air. For further particulars on this subject the student is recommended to consult any elementary work on natural philosophy.

Intake.—The road along which the fresh air passes into the mine is called the "intake," and the current that flows along it is called the "intake air."

Iron Pyrites.—This is a mineral substance frequently found in coal, and called by the miners of England "brass" or "brazil." It is sulphide of iron, and the chemists give it the symbol of $Fe\,S_2$. When pyrites is present in coal heaps, its oxidation frequently gives rise to what is known as spontaneous combustion, although such occurrences may take place without the presence of this substance.

Lampman.—The man who attends to the cleaning, trimming and lighting of the safety-lamps.

Lamp Station.—(Eng.) The place in the mine where the lamps are re-lit, in case of their having gone out, and to where they are to be taken if they require attending to. The station should be placed in the intake air-current.

Manometer.—Another name for water-gauge.

Manometrical Effect.—Manometrical effect or manometric yield is the proportion which the actual water-gauge of a mine bears to the theoretical water-gauge. The actual water-gauge

may be observed by taking the reading of the instrument in a fan drift. The theoretical water-gauge is calculated by the following rule:

Let f = weight of a cubic foot of air in pounds.
Let g = force of gravity = 32·2.
Let v = velocity in feet of tips of fan per second.
Let w = water-gauge in inches; then

$$w = \frac{\frac{v^2}{g} \times f}{5{\cdot}2}$$

Marsh Gas.—Carbureted hydrogen or fire-damp, known likewise by the names of methyl hydride and methane. The chemical symbol is CH_4.

Mephitic Gas.—Animal effluviæ and exhalations, which become not only offensive but poisonous when a number of men or animals are huddled together in a limited space unprovided with ventilation.

Motive Column.—A head of air, or the length of an air column, generally reckoned in feet, of the same density as the flowing air, equal to the pressure producing the ventilation.

Mueseler.—The name of a safety-lamp invented by Mueseler. Its construction is similar to the Clanny, but it is provided with a conical shaped chimney supported by a horizontal gauze on the top of the cylinder. It gives a pleasant light, and has proved to be safer in practice than either the Davy or Clanny. The illuminating power of this lamp is much greater than either the Clanny, Stephenson, or Davy. It is extensively used in the coal mines of the Continent and England.

The bonneted Mueseler was one of the safety-lamps recommended by the members of the Royal Commission on Accidents in Mines, 1886. (Great Britain.)

Natural Ventilation.—The air-current due only to the difference in temperature between the outer air and that of the mine. In some small collieries this is sufficient for all purposes; indeed in some large mines it is relied upon, and as an instance the writer may mention the case of Walsall Wood, in Staffordshire, a large and very deep mine. The downcast and upcast are both of the same diameter—if he believes rightly, about 16 feet—and the ventilation of the underground workings is carried on continuously without the aid of either a fan or furnace. It is not generally reliable, as the variation of the temperature sometimes causes the direction of the air-current to change, which we know by experience.

Naked Light.—An open unprotected light, not provided with gauze or anything else.

Old Man.—Same as gob or goaf.

Perimeter.—The measure of the outline of a section of a figure; thus, the perimeter of a road 4 ft. square would be 16;

the perimeter of a road 6 ft. by 5 ft. would be $6 + 5 + 6 + 5 = 22$. The perimeter of a circular shaft or tunnel 10 ft. diameter, would be $10 \times 3{\cdot}1416 = 31{\cdot}416$ ft.

Pieler Lamp.—This may be described as a large Davy lamp, constructed to burn alcohol with an argand wick. The air supplied to the inner part of the flame is admitted by a tube, protected by superposed discs of gauze, which passes vertically through the vessel containing the alcohol. Around the flame is a short, conical chimney, open above and below, and the flame is so regulated that it does not appear above the chimney, its height being, therefore, from 1 to 1·25 inches. In gas this spirit flame yields a much more conspicuous cap than can be produced by the flame of ordinary vegetable or animal oil. It is a sensitive gas detector, and in the form now used the flame is extinguished by the ignition of the gas.

Piped Air.—Air passed through tubes or pipes to ventilate advance headings.

Plenum.—"A mode of ventilating a mine or a *heading* by forcing fresh air into it." (W. S. Gresley).

Power of Ventilation.—The amount of force in operation to produce the current of air in circulation. It may be reckoned in units of work or horse-power, and is obtained by multiplying the pressure by the quantity.

Pressure of Ventilation.—This is the motive-force obtained by rendering one end of an air-current of less density than the other, and the flow of the air will be in the direction of the rarefied air; this may be done either by heating the air or by exhaustion in the upcast. The difference of density between the intake and return is generally measured by the water-gauge.

Propane.—A mixture of carbon and hydrogen, (C_3H_8.) A small proportion of this gas has been found in samples of the natural gas issuing from the Pennsylvania oil regions.

Quantity.—When the ventilation of a mine is spoken of in England and America, it is generally said that the quantity passing is so many cubic feet per minute; on the Continent the quantity is reckoned in cubic metres.

Réaumur.—A celebrated French naturalist, a member of the Academy of Sciences, B. 1683, D. 1757. He was the inventor of the thermometer which bears his name, by the scale of which, the freezing point is fixed at zero (0°) and the boiling point at 80°. (See Thermometer, Centigrade, and Fahrenheit.)

Reciprocal.—When the writer has used this word he intends it to signify the result of a number divided into one; thus, the reciprocal of $2 = {\cdot}5$, of $4 = {\cdot}25$, and of $8 = {\cdot}125$, etc. One quantity is the reciprocal of another, when the one is the result of unity divided by the other. The product of a quantity by its reciprocal must always be unity. The student should remember this mathematical expression, which is sometimes made use of in calculations referring to ventilation as in the state-

ment : "when the air-courses are of the same area and perimeter, and the pressure is the same, the quantities are in proportion to the reciprocal of the square root of the length."

Regulator.—A stopping or door having a hole in it to allow a scale of air to pass through in just sufficient quantity for ventilating the district through which it has to pass. Air always takes the short cut, or the road where there is the least resistance ; hence, in short splits or roads to the return or the upcast it is necessary to regulate the air passing in these short roads by allowing only the necessary quantity of air to pass through a scale or regulator.

Resistance.—This means the same as the drag or friction of the air.

Return.—This means the road or channel through which the air flows on to the upcast, after it has passed through the workings of the mine. Return air is the air which has traveled through the mine.

Rise-workings.—Openings in a mine which are above the bottom of the shaft or slope—to the rise—or up towards the crop.

Rubbing-Surface.—The area of the roof, bottom and sides of the passage against which the air rubs as it flows along, and is generally expressed in square feet. For example, if an air road be 1000 yards long, 6 ft. high and 7 ft. wide, the rubbing surface will be 78,000 square feet.

Safety-Door.—A strongly constructed door kept in readiness should the main door or separation door be blown down by an explosion. The hinges are so made that the door can swing up against the roof, from which a sufficient space has been cut away, where it remains quite out of the way in ordinary times, but ready for use in case of accident. A door of this kind, called an "extra main-door," according to the Anthracite Mine Law of Pennsylvania, shall be placed and kept standing open, out of the reach of accident so that it can be at once closed in the event of an accident to the doors in use.

Safety-Lamp.—A lamp constructed for the safety of the miner, designed to prevent fire-damp from exploding. There are many varieties, some of which have been referred to under the headings of Davy, Stephenson, Mueseler, etc.

Scale of Air.—A small portion of air allowed to pass from the main current to ventilate some isolated place.

Sound Wave.—An undulatory movement of the air, which may be caused in a mine by the firing of a shot, or a fall of roof; in this way one mass of air is passed on to another. There is strong presumptive evidence that many explosions of gas have been occasioned by sound waves where the Davy lamp—the most dangerous of all safety-lamps—has been in use.

Split.—A division of the air-current; a current of air separated from the main air-current. To split the air is to send the

current along two or more roads instead of one. By dividing one current into two *equal splits* there will be two roads, each of half the length, but of the same area as the original air-way; with three equal splits there will be three roads, each one-third the length, but of the same area, as the original air-way, and so on; at least that is the meaning intended by Atkinson in his treatise on the "Friction of Air in Mines."

In practice, however, the conditions he calculates upon, do not exist in a mine. The calculations illustrate the advantages of splitting the air, so far as it can be done practically. When the same quantity of air is required in each split, it is well to have the passages of equal length and area, so that regulators may be avoided. See paragraphs 33 and 34, Chap. I.

Square Root.—A number which, multiplied into itself, gives the square number; thus, 3 is the square root of 9.

Standing Gas.—A quantity of gas existing in an underground excavation through which no current of air is passing.

Static Gauge.—This word has recently been introduced into the literature of mine ventilation to signify the water-gauge placed in a recess of the main return air-drift a short distance to the windward of the fan. It is placed in this position so as to be away from the influence of the eddies of the air-current, and to give a true reading of the actual pressure producing the ventilation of the mine.

Steam Jet.—An arrangement by which steam is allowed to escape at high pressure from a large number of small orifices, made in iron pipes, upwards into the upcast, thereby producing an air-current. This mode of producing ventilation is not so efficient as the other methods. A comparison of the economy of four ways of ventilating is given in the *Transactions* of the Mining Institute of Scotland, Vol. 1, from which the following particulars are taken:

Mode of Ventilation.	Proportion of coal required for a given quantity of Air.
Steam jet	1000
Furnace	350
Centrifugal open running fans	150
Centrifugal fans on the Guibal Principle	120

Stephenson.—The name given to the safety-lamp invented by the celebrated George Stephenson. It has proved to be in practice a safer lamp than the Davy, but it does not give so good a light. In the construction of this lamp there is an internal glass cylinder with a perforated metal cap, surrounded by a cylindrical gauze. The air necessary for the combustion of the wick passes through perforations in the frame of the lamp, through the lower part of the gauze, and below the glass.

Stone-damp.—See *White-damp.*

Stythe.—A word used in the Northumberland and Durham coal field, meaning choke-damp, or carbonic acid gas. This

gas is likewise called black-damp. The writer may say here that he has found in his experience—in the Five-quarter Seam, Blackboy Colliery, Durham—that a body of gas in a goaf or gob, will at one time give indications of black-damp, and at another time will indicate fire-damp; the change in the indications is probably due to the altered conditions of the outward atmosphere as regards pressure and temperature.

Sulphur.—A word frequently used amongst the South Staffordshire miners to signify carbureted hydrogen, and likewise formerly by the old miners of Durham.

Thermometer.—An instrument for indicating variations in temperature. It generally consists of a slender glass tube, having a bulb at one end, and being sealed at the other. The bulb and a portion of the tube contain mercury, the rest of the tube being a vacuum. When the temperature is raised or lowered, the mercury expands or contracts, so as to occupy a portion of the tube less or greater than before, and the amount of expansion or contraction is indicated by a scale attached to the instrument. The Fahrenheit scale is used generally in England and the United States of America, the Réaumur in France, and the Centigrade in Germany. (See Fahrenheit, Centigrade, Réaumur.)

Troughs.—A word used in Staffordshire, meaning the iron tubes used for passing air through.

Units.—A mechanical expression meaning the pounds lifted one foot high in a minute. The pressure per square foot of the ventilation (in pounds) multiplied by the cubic feet of air passing per minute will give the number of units; 33,000 units = 1 horse power.

Upcast.—The shaft through which the return air of a mine ascends.

Velocity.—The speed at which air travels, generally reckoned at so many feet per second or minute and is usually ascertained by the revolutions of an anemometer. The speed multiplied by the area gives the quantity.

Ventilate.—To pass fresh air by or through.

Ventilating Fan.—A revolving machine placed at the top of the upcast for exhausting the air from a mine. As it revolves it maintains a partial vacuum at the top of the shaft, which the air of the mine comes in to fill, and so a current is created. The fans now in operation are of various kinds, known by the names of the inventors, such as Waddle, Guibal, Fabry, Lemielle, Nixon, Root, Struve, Capell, Rammell, Schiele, Chandler and others.

Ventilator.—Same as ventilating fan.

Waste.—Means generally in the North of England, the return part of a mine. In Cannock Chase district, the vacant space in the gob, along the face between two stall roads.

Wasteman.—A man who looks after the ventilation or air roads. (Northumberland & Durham coal field.)

Water-blast.—If by any means water should find its way into the bottom of a shaft, from which the workings are extended to the rise, and the water should ascend in the shaft, the water will not extend into the whole of the upper workings, on account of the air there, which acts like a cushion as it becomes pressed into a smaller space as the water fills up the shaft. The pent-up air of the mine, and the water in the shaft will be in equilibrium. When the water comes to be pumped from the shaft, as it is lowered, the equilibrium will be destroyed, and eventually the compressed air will rush out with some force, causing a sudden rising of the water in the shaft. This phenomenon is known as a water-blast which Mr. W. S. Gresley in his Glossary says is "the sudden escape of pent-up air in *rise workings* under considerable pressure from a head of water which has accumulated in the lower workings."

The following description of this phenomenon appeared in the *Colliery Guardian* of March 4th, 1892.

Suppose a colliery with inclined measures to be abandoned or possibly having to be flooded to extinguish fire; the air on the rise side of the shaft will be shut off from any exit and compressed by the water as it rises in the shaft and advances into the rise workings. When the water assumes a great height in the shaft, this compressing force is very great and the air, through its elasticity, reacts with the same force. If anything occurs to destroy this equality of forces, and the air gains preponderance, this will surely happen, if the mine has to be unwatered it will break its confinement and rush to the shaft in great volumes; here, its elastic energy reacting first, lifts the whole body of water in the shaft up; next freeing itself from the water it suddenly assumes its normal volume and escapes from the shaft at a very high velocity, and the water subsides to a point far below its usual level. In brief, a drowned-out mine is the condition essential to a water-blast. The phenomena are a sudden uprising of the water in the shaft accompanied with considerable noise, a discharge of air probably charged with gas at high velocity, and a sudden subsidence of the water in the shaft.

Water-gauge.—An instrument formed of a glass tube in the shape of the letter U. When one end of it is passed through a small hole in a partition between the intake and return air, the difference of the height of the water in the two legs, is a measure of the pressure of the ventilation. If the difference be one inch, the presure will be 5·2 lbs. per square foot; if two inches, 10·4 lbs.

Watery Vapor.—The moisture contained in the atmosphere. A given volume of air cannot take up more than a certain quantity of moisture at a given temperature, but when it takes up that quantity it is said then to be saturated with it. As the temperature of the air increases, it becomes capable of taking up more water. The average amount of water held in sus-

pension is about a pint in 2,500 cubic feet of air. The return air of coal mines is often saturated with watery vapor.

White-damp.—The name given by some miners to carbonic oxide: from what took place at the spring meeting, 1893, of the Illinois Mining Institute, it appears likewise to be called *stone-damp.* This gas is described in par. 70, Chap. I.; we may, however, add here that it is composed in volume of one part of carbon and one of oxygen. It is highly explosive when two parts of it are mixed with five parts of air. Some of the explosions which have occurred in the mines of Staffordshire have been attributed to the presence of this gas—originating from gob-fires.

It is found in mines, especially where gob-fires exist, and is produced by imperfect combustion. It is frequently met with in the mines of South Staffordshire, where gob-fires are very general. It is found in small quantities in the after damp of colliery explosions. It is present in considerable quantities in the after-damp formed in explosions where coal dust forms part of the combustible material. It is formed by the combustion of gunpowder, and in all cases where carbon is not sufficiently burnt for want of oxygen.

It is to be seen over a still red fire in a furnace burning with a blue flame.

It is generated spontaneously in a gob from the accumulation of slack left there.

It has been found in a very small proportion, in some samples of fire-damp in Germany, and in the natural gas of Pennsylvania.

Excepting possibly in a very small degree, it is not likely to be present in a mine without combustion of some kind be going on somewhere in the workings of the mine.

Wind-cowl.—An iron tube made somewhat in the form of the trumpet like pipes which are to be seen on the decks of steamers for sending down a current of air into the cabins. This arrangement is used at the mines of Scotland and elsewhere for sending fresh air into a mine, but any current obtained by this means is very uncertain and irregular. This contrivance is to be seen at some of the shallow mines of South Staffordshire where it is called a *horse's head.*

Wind-gauge.—An instrument for obtaining the speed at which air travels in a mine, the same as anemometer.

Wind-way.—The same as air-way.

CHAPTER III.

PRACTICAL NOTES ON COAL DUST AND COLLIERY EXPLOSIONS.

Any treatise on the subject of mine ventilation and colliery explosions must necessarily be incomplete without some reference to the question of coal dust.

The subject is one of great importance, considering the large number of lives which are lost from colliery explosions. The following statement shows the loss of life in Great Britain from this cause :

Years.	Average number of lives lost per annum.	One life lost to number of persons employed.
Ten years to 1860	244	1008
Ten years to 1870	226	1414
Ten years to 1880	269	1795
Ten years to 1890	166	3199
Year 1891	51	12714
Year 1892	123	5400

Recent reports of the inspectors of mines, in the different States, have drawn attention to the serious effect coal dust has on explosions, especially in extending them. The inspector for the Second Bituminous district of Pennsylvania, in his report for 1891, recommended the coal dust of dry mines to be dampened. In the anthracite coal mines of Pennsylvania, in 1891, the number of lives lost by explosions was 38, and in the bituminous mines, 111.

It has long been known that the presence of coal dust in very deep mines, in the case of an explosion of fire-damp, very much intensifies the force and extent of the explosion.

During the last few years it has been repeatedly asserted by some of the British inspectors of mines, that an explosion will occur from coal dust in itself, without the presence of fire-damp.

One of the principal objects the writer has in view in making these remarks is to induce the coal miners, as well as the mine officials, to take an interest in the question, and consider it for themselves.

Dr. Lyon Playfair and Professor Faraday, in reporting, in the year 1845, on the Haswell Colliery explosion, County of Durham, which occurred the year previously, stated that they had

found the clothes of the miners scorched and crusted over more or less with coke and ash, owing to the presence of coal dust. Sir Frederick Abel, in publishing the results of his investigations into an explosion at Seaham Colliery, stated that dust which contained very little coal was often able to produce almost as much effect in causing the fire, as dust which was almost purely coal. That was confirmed by the fact that he could produce the same results by mixing gas and air with fine slate dust, clay dust, powdered pumice, and even powdered magnesia—all powders which no one would imagine would burn in themselves. From this it is concluded that all dust, not only the dust of pure coal, is more or less dangerous.

The reports of the British inspectors of mines for recent years contain several references to the part played by coal dust in explosions, and as they bear so closely to the subject under consideration, the writer considers it advisable that he should draw attention to some of them. On April 24, 1889, an explosion occurred at Brancepeth Colliery, Durham, from the light of an open torch lamp used by the workmen in cleaning out the fine dust from the hoppers, by which three men lost their lives. The verdict returned at the inquest was "Death caused by the firing of coal dust coming in contact with naked lights," with the recommendation that no naked lights be taken into the coal hoppers in the future.

In his report on the Mossfields Colliery explosion, which occured on October 16th, 1889, the mine inspector says: "This disaster is another example of how an explosion is extended by coal dust, and the loss of life greatly increased in consequence. The normal condition of a dry and dusty colliery, or of a colliery in which the roads connecting different districts are dusty, is such that a terrible explosion is possible at any moment." On November 4th, 1889, an explosion occurred at Hebburn Colliery, of which the inspector said he did not feel justified in calling it entirely an explosion of fire-damp. The hole was charged with gelignite and roburite together, and in the opinion of the inspector, the explosion was caused by the flame being blown out from this fast shot, assisted by any small quantity of fire-damp that might be present. Another example of coal dust exploding without the presence of fire-damp took place in 1890 on the pit-bank at one of the collieries in the Yorkshire district, particulars of which are given by the inspector in his annual report. Some very fine coal dust had accumulated on a plank; in turning over the plank, which it was necessary to move in making some repairs to an engine, the dust fell upon torch-lights and an explosion occurred and burnt several of the men very seriously. Coal dust is exceedingly dangerous when mixed with a small quantity of fire-damp, 4 per cent. of gas mixed with air will not explode, but it will when fine coal dust is mixed with it. In 1890, Mr. Henry Hall, one of the inspectors of mines in Great Britain, made certain experiments in

three different shafts to ascertain if coal dust by itself is explosive. The way he proceeded was to sprinkle fine dust in the shaft and fire off a cannon pointed upwards, placed at the bottom of the shaft in each case. In several cases the dust was ignited, and the flame ascended the shaft and rushed out of its mouth at the top to a height of from 20 to 40 feet. From these experiments he concludes that they "prove that blasting with gunpowder in dry and dusty mines may cause serious disasters in the entire absence of fire-damp." With respect to these experiments it may be remarked that the action of a flame amongst coal dust must necessarily be very different in a horizontal gallery to what it would be in a vertical shaft; for the tendency of flame is to rise, the same "as the sparks fly upward," and it may be doubted whether such a result would be obtained in firing a cannon along the level road of a mine as that in a vertical shaft.

Further experiments of a similar kind, though under somewhat altered conditions, were made by the same inspector in a Lancashire pit, England, at the end of 1892, and beginning of 1893, which have confirmed his opinion that explosions will occur from coal dust by blown out shots without the presence of fire-damp.

The experiments were made by firing off a cannon, with a charge of about 1¼ lbs. of gunpowder, into a shaft in which a quantity of fine coal dust was floating, or which was deposited on the timber in the shaft, which was wet; the shaft was 50 yards deep and 7 feet diameter, having pieces of timber fixed across every 6 or 7 feet at the side to represent timbering underground, and to afford a lodgment for the dust.

The experiments were made with and without the working of a small hand fan which, when operated, blew the air down 10-inch pipes to the bottom of the shaft.

From these experiments Mr. Hall deduced the conclusions that:

1. Dry coal dust, under conditions frequently present in coal mines, and in the entire absence of fire-damp, may be inflamed by a blown out gunpowder shot and cause a disastrous colliery explosion.

2. An explosion will occur when there is actually no coal dust in suspension, but when it is lodged on the timbers or on the sides.

3. A gunpowder shot will explode coal dust, whilst blasting with roburite will not do so.

4. Any colliery in which the seams are naturally of a dry and dusty character cannot be successfully damped so as to render gunpowder safe.

5. With the increased ventilation produced by the operation of the fan the experiments were more decisive, showing that the brisker the ventilation of a mine the greater the danger from coal dust.

Explosions have occurred from small particles of other substances besides coal, such as flour, cotton flue, rice dust and sawdust. In June, 1892, an explosion of malt dust occurred in one of the top stories of Bell's Brewery, Stafford, by which the roof was blown off and considerable damage done, and numerous instances are on record of explosions of flour dust taking place in flour mills.

An explosion of this sort took place on March 24th, 1893, at the Keeler Flouring Mill, Litchfield, Ill., when the immense structure was blown to fragments.

There is a considerable difference in the chemical composition and mechanical structure of various samples of coal dust; there is a difference in the chemical composition of the dust of the same coal, brought about by time; new coal dust and old coal dust have very different compositions, because the oxygen in the air will remove some of the constituents.

The writer possesses the settled conviction that the dust of the coal mines of many coal fields is inexplosive; this opinion is forced upon him from the fact of the immunity of these mines from explosions of dust during the whole period of their history. Various examples may be mentioned—one will be given in the absence of any special experiments being made to test the question, but after fourteen years' observation, it is the opinion of the writer and many mining engineers of the Cannock Chase district, Staffordshire, England, that the dust in the underground workings of the collieries there will not explode of itself, nor will it intensify or extend an explosion of fire-damp. Neither collier or manager can see any danger from coal dust in these mines; the dust is more of an argillaceous than carbonaceous character. It must be borne in mind however, that Sir Frederick Abel, in speaking of certain dust of the Seaham Colliery, says it may be a source of danger even though it contains only a small proportion of coal or combustible matter; in fact, Sir Frederick ascertained that a dust which would not itself burn could possibly aid in making a mixture of gas and air explosive. Fire-damp, as it escapes from the coal in a mine, is not explosive; it requires to be mixed with air in certain proportions before it will ignite. With a mixture of one of gas and twenty of air there will be no explosion.

Some mining engineers have questioned the statement that it is possible in a shot hole, where gases are given out by feeders, that firing a shot will ignite the feeder. The writer, in his own experience, can mention one case, at least, where the firing of a shot by gunpowder set fire to a feeder of gas; the gas continued to burn a considerable time afterwards, with a flame several feet long. This occurred in driving a tunnel from the Catherine seam to the Gustavus seam, at Hansa Colliery in Westphalia. There are many other similar occurrences on record. It has been argued that a feeder of gas at the back of a hole could obtain no atmospheric air—there would be an

absence of oxygen—and without that element the gas could not be ignited. It is true that if a flame be introduced into gas there would be no ignition without air; but the composition of the gases given off from coal or the associated rocks varies very much, and in firing a shot, the necessary oxygen might get access to occasion explosion.

About two years ago a Commission was appointed in England, of which the Right Honorable Joseph Chamberlain is Chairman, to enquire into the dangers of coal dust in mines, before which numerous witnesses have been examined, including both mining and scientific experts. The labors of this Commission are not yet ended, but we believe will shortly be brought to a close, after which will come the publication of their report.

No coal dust explosion has taken place in the actual experience of the writer in any of the mining districts in which he has been engaged during his career.

CHAPTER IV.

RULES AND FORMULÆ APPLICABLE TO VARIOUS QUESTIONS RELATING TO THE VENTILATION OF MINES, THE PRESSURE AND TEMPERATURE OF THE ATMOSPHERE, AND TO THE CIRCULATION OF AIR IN PASSAGES, ETC.

The subject of mine ventilation is one that ought to be studied by every intelligent miner, as well as colliery official, for the safety of a mine, especially as regards ventilation, depends not only upon the competency of the mine officials, but upon the action of every indivdual in the mine whatever his position may be. In studying the subject the miner should be able to attack it from any position. With this in view the writer has brought together a number of rules and formulæ applicable to the subject under various conditions and circumstances. Some of the formulæ have appeared elsewhere and have almost become the common property of engineers generally; many of them are quite new, others are presented in a new form, and all have been arranged with a view of being practically useful. Although the rules might be elaborated and extended, the writer believes sufficient are given to enable the student to consider the subject in the various aspects in which it may be presented, and to work out most of the questions that may be met with in practice.

Many other rules relating to the co-efficient of friction might be given under VII.; indeed, more will be found in the table of co-efficients, which will appear in the next chapter. With regard to the co-efficient of friction, the writer must maintain that

his co-efficient of ·00000001 lbs.* per square foot for a velocity of one foot per minute, which he has always recommended, is sufficient as an average for the air passages of coal mines, and he has worked out numerous examples accordingly, as will be seen in these papers further on. Murgue, in experiments on the subject, which he has recently published, makes it less even than the writer puts it at. It must be remembered, however, that it varies with the nature of the sides of the channels, that it increases in roads of small section as the area diminishes,—that, in fact, it is a variable factor.

I. The following rules apply to the friction of air in moving along passages and underground roads: Let a = area of air-ways in square feet; h = horse power of ventilation; k = co-efficient of friction; l = length of air-channel; o = perimeter of air-channel; p = pressure in pounds per square foot; q = quantity of air circulating, in cubic feet per minute; s = area in square feet of rubbing surface exposed to the air; u = units of work, foot pounds, or power applied to circulate the air; v = the velocity of the air in feet per minute; w = water-gauge in inches; then

1. $a = \dfrac{k\,s\,v^2}{p} = \dfrac{p\,a}{p} = \dfrac{k\,s\,v^2\,q}{u} = \dfrac{k\,s\,v^3}{p\,v} = \dfrac{u}{p\,v} = \dfrac{q}{v} = \dfrac{q}{\sqrt[3]{\dfrac{u}{k\,s}}}$.

2. $h = \dfrac{u}{33{,}000} = \dfrac{q\,p}{33{,}000} = \dfrac{q\,w\,5{\cdot}2}{33{,}000}$.

3. $k = \dfrac{p\,a}{s\,v^2} = \dfrac{u}{s\,v^3} = \dfrac{p}{s\,v^2 \div a} = \dfrac{w\,5\frac{1}{5}}{s\,v^2 \div a}$.

4. $l = \dfrac{s}{o} = \dfrac{p\,a}{k\,v^2\,o}$.

5. $o = \dfrac{s}{l} = \dfrac{p\,a}{k\,v^2\,l}$.

6. $p = \dfrac{k\,s\,v^2}{a} = \dfrac{u}{q} = 5\frac{1}{5}\,w = \left(\sqrt[3]{\dfrac{u}{k\,s}}\right)^2 \dfrac{k\,s}{a} = \dfrac{p\,a}{a} = \dfrac{k\,s\,v^3}{q} = \dfrac{u}{a\,v}$.

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* The co-efficient generally used is that of J. J. Atkinson,—·0000000217. The writer has found from numerous observations of the flow of air in shafts and mines, that this is far too high and that ·00000001 is a more correct factor for most cases. Murgue in his recently published paper on the subject makes it less even than this (See COLLIERY ENGINEER, August, 1893, p. 16). If it be required to ascertain the result from a higher or a lower co-efficient, it may be done by direct proportion;—for example, if the writer's co-efficient gives a pressure of 1 lb., Atkinson's will give 2·17 lb. Particulars of a large number of co-efficients are given in Table 1 of next chapter.

7. $p\,a = k\,s\,v^2 = \left(\sqrt[3]{\frac{u}{k\,s}}\right)^2 k\,s = \frac{u}{v}$.

$p\,a^3 = k\,s\,q^2$.

8. $q = v\,a = \frac{u}{p} = \frac{k\,s\,v^3}{p} = \sqrt{\frac{p\,a}{k\,s}}\,a = \sqrt[3]{\frac{u}{k\,s}}\,a = \frac{h\ 33{,}000}{w\ 5{\cdot}2}$,

9. $s = \frac{p\ a}{k\,v^2} = \frac{u}{k\,v^3} = \frac{q\ p}{k\,v^3} = \frac{v\,p\,a}{k\,v^3} = l\ o$.

10. $u = q\,p = v\,p\,a = \frac{k\,s\,v^2\,q}{a} = k\,s\,v^3 = q\,5\frac{1}{5}\,w = h\ 33{,}000$.

11. $v = \frac{u}{p\,a} = \frac{q}{a} = \sqrt[3]{\frac{u}{k\ s}} = \sqrt[3]{\frac{q\ p}{k\ s}} = \sqrt[2]{\frac{p\ a}{k\ s}}$.

12. $v^2 = \frac{p\,a}{k\ s} = \left(\sqrt[3]{\frac{u}{k\ s}}\right)^2$

13. $v^3 = \frac{u}{k\ s} = \frac{q\ p}{k\ s} = \frac{v\ p\ a}{k\ s}$.

14. $w = \frac{p}{5\frac{1}{5}} = \frac{k\ s\ v^2}{a} \div 5\frac{1}{5}$, etc.

II. To ascertain the motive column or the head of air due to difference of temperature, etc.

Let M = motive column.
Let T = temperature of upcast.
Let f = weight of one cubic foot of the flowing air.
Let t = temperature of downcast.
Let D = depth of downcast.
Then,

$$M = D\,\frac{T - t}{T + 459} \text{ or } \frac{5{\cdot}2 \times w}{f}.$$

$$p = f \times M.$$

$$w = \frac{f \times M}{5{\cdot}2} = \frac{p}{5{\cdot}2}.$$

III. Rule to find diameter of a round air-way to pass the same amount of air as a square air-way, the length and power remaining the same.

Let D = diameter of round air-way.
Let A = area of square air-way.
Let O = perimeter of square air-way.
Then,

$$D = \sqrt[5]{\frac{A^3 \times 3{\cdot}1416}{{\cdot}7854^3 \times O}}.$$

IV. Rule to find the relative pressure or powers (Rp) required to pass equal quantities of air through air-courses of the same length, but of different areas and perimeters.

$$\mathrm{R}\,p = \mathrm{O}\left(\frac{1}{a}\right)^3$$

V. Rule to find the relative quantities (Rq) that will pass airways subject to the same pressure, but of different dimensions.

$$\mathrm{R}\,q = \sqrt{\frac{a^3}{s}} \text{ or } \sqrt{\frac{a}{\sqrt[3]{s}}}.$$

VI. Rule to reduce a continuous undivided road of various dimensions, to one typical road of uniform size throughout :

$$l = \frac{a'^3}{o'} \times \frac{s}{a^3}.$$

a' = area of typical road, o' = perimeter of same.
s and a = rubbing surface and area respectively of the original uneven road at each series of dimensions.

VII. Rule to convert the French (F) co-efficient of friction, or head of air, to the English (E) co-efficient, that is to say, the water-gauge in millimeters for each square meter of rubbing surface and a velocity of one meter per second, to the pressure per square foot in decimals of a pound for each square foot of rubbing surface, and a velocity of one foot per minute :

$$\mathrm{E} = \frac{\mathrm{F} \times \cdot 0393708 \times 5{\cdot}2}{10{\cdot}76458 \times 60^2}.$$

When w = ·00000001 lb. per square foot of rubbing surface for a velocity of 1 foot per minute, then

$$v = 10{,}000\sqrt{\frac{p\,a}{s}}.$$

VIII. To find the quantity of air with a given horse power (h) and efficiency (e) of engine :

$$q = \frac{h \times 33{,}000 \times e}{p}.$$

IX. To find the weight (W) of a cubic foot of air at any temperature or height of the barometer :

B = height of barometer in inches.
t = temperature F.

$$\mathrm{W} = \frac{1{\cdot}3253 \times \mathrm{B}}{459 + t}.$$

X. Formulæ for converting the different thermometer scales into each other. F, C, and R represent Fahrenheit, Centigrade and Réaumur respectively :

$$F = 32 + \frac{9}{5} C = 32 + \frac{9}{4} R.$$

$$C = \frac{5}{9} (F - 32) = \frac{5}{4} R.$$

$$R = \frac{4}{9} (F - 32) = \frac{4}{5} C.$$

XI. Rule to measure the air in a mine by gunpowder.

Select an even part of the road from 50 to 100 feet in length ; ascertain its cubical contents in feet, let off a flash of gunpowder at one end of the road, and observe how long the smoke is in passing to the other end, then as the time in seconds in passing is to the cubic area, so is 60 seconds to the number of cubic feet passing per minute.

XII. Formulæ relating to equivalent orifice :

Let Q = quantity of air in thousands of cubic feet per minute,
w = inches of water-gauge.
A = area in square feet of equivalent orifice, then,

$$A = \frac{0{\cdot}37\ Q}{\sqrt{w}} = \frac{Q}{2{\cdot}7\sqrt{w}}.$$

$$Q = \frac{A \times \sqrt{w}}{0{\cdot}37}.$$

$$w = 0{\cdot}1369 \times \left(\frac{Q}{A}\right)^2.$$

XIII. Rules and formulæ relating to the theoretical depression, or pressure of air due to final velocity :

Murgue says : The theoretical depression or water-gauge, due to the speed of the periphery is, in a perfect ventilating fan, equal to twice the height of column of air necessary to generate such velocity in a falling body. From this proposition we give the following rules :

Let v = velocity in feet of tips of fan per second.
Let g = force of gravity = 32·2.
Let M = pressure in feet of air or motive column.
Let w = pressure in inches of water-gauge.
Let f = weight of a cubic foot of the flowing air in lbs.; then,

$$M = \frac{v^2}{g} = \frac{v^2}{32{\cdot}2} = w \times 68.$$

$$w = \frac{M}{68} = \frac{M \times f}{5{\cdot}2}.$$

$$v = 8{\cdot}025\sqrt{\frac{M}{2}}.$$

The factor 68, in these rules has been obtained by reckoning water 816 times heavier than air, which, although it varies with the temperature, is the ratio at a temperature of 62° F.; so that to get the pressure expressed from head of air in feet into inches of water-gauge, we have $\frac{816}{12} = 68$. The factor for other temperatures would be more correctly $\frac{5{\cdot}2}{f}$; or, $\frac{d}{d'}$ divided by 12, d being the density of water, and d' the density of air at the same temperature.

XIV. If two fans are employed to ventilate a mine, each of which when worked separately produces a certain quantity, which may be indicated by A and B, then the quantity of air that will pass when the two fans are worked together will be $\sqrt[3]{A^3 + B^3}$.

CHAPTER V.

USEFUL TABLES RELATING TO MINE VENTILATION, AIR AND GASES.

The tables annexed, the greater number of which are entirely original, have been prepared by the writer to facilitate calculations relating to the motion, pressure, and expansion of air and other matters connected with the ventilation of mines.

I. Table of the co-efficient of friction in the flow of air, through passages with different kinds of surface according to the undermentioned authorities, expressed in different terms agreeable to the measures used in the United States, Great Britain, France and Germany.

Number.	Name of Authority, Place, and kind of Passage.	For each foot of rubbing surface and a velocity of 1000 feet per minute.			For each square meter of rubbing surface and a velocity of one meter per second.	For each square foot of rubbing surface and a velocity of one foot per second	For each square foot of rubbing surface and a velocity of one foot per second	For each square foot of rubbing surface and a velocity of one foot per second	For each square foot of rubbing surface and a velocity of one foot per minute.
		Air column in decimals of a foot.	Pressure per square foot in decimals of a pound.	Water-gauge in inches.	Water-gauge in m. m.	Air column in decimals of a foot.	Pressure per square foot in decimals of a lb.	Water-gauge in inches.	Pressure per square foot in decimals of a lb.
		$\frac{B}{\cdot080728}$	$C \times 5{\cdot}2 = A \times \cdot080728$	$D \times \cdot0393708 \times 1000^2 = 10{\cdot}76458 \times 60^2$	$H \times 60^2 \times 10{\cdot}76458 = \cdot0393708 \times 5{\cdot}2$	$\frac{A \times 60^2}{1000^2}$	$E \times \cdot080728$	$\frac{F}{5{\cdot}2}$	$\frac{B \times 1000^2}{A \times \cdot080728 \times 1000^2}$
		A	B	C	D	E	F	G	H
1	*J. J. Atkinson*..... *A. Devillez.* in his "Ventilation des Mines"	·26881	·0217	·004173	·004107	·000967716	·0000781217	·0000150234	·0000000217
2	Forchies.....	·10171	·008211	·001579	·001554	·000366156	·0000295590	·0000056844	·0000000008211
3	Crachet-Picquery.....	·11060	·008928	·001717	·00169	·000398160	·0000321427	·0000061813	·0000000008929
4	Grand Baisson.....	·10667	·008611	·001656	·00163	·000384012	·0000310005	·0000059616	·0000000008612
5	Average of 2, 3 and 4.....	·10635	·008585	·001651	·001625	·000382860	·0000309075	·0000059437	·0000000008586
6	Adopted by Devillez.....	·11781	·009511	·001829	·0018	·000424116	·0000342380	·0000065842	·0000000009511
7	Arched Tunnels.....	·02617	·002113	·000406	·0004	·000094212	·0000076055	·0000014626	·0000000002113
8	Working Face.....	·17671	·014266	·002743	·0027	·000636156	·0000513556	·0000098761	·0000000014266
9	*G. G. André*.....	·27777	·022424	·004312	·004244	·001000000	·0000807280	·0000155246	·0000000022424
10	*Peclet.* Chemmee. (Devillez p. 112)	·04579	·003697	·000711	·00069	·000164844	·0000133092	·0000025596	·0000000003697
11	*D. K. Clark*.....	·02814	·002272	·000437	·00043	·000101304	·0000081792	·0000015732	·0000000002272
12	*Goupilliere*, "Cours de Exploitation des Mines" D'Aubuisson.....	·02421	·001955	·000376	·00037	·000087156	·0000070380	·0000013542	·0000000001955
13	Navier.....	·02318	·001872	·000360	·00035	·000083448	·0000067392	·0000012960	·0000000001872
14	*W. Fairley.* "Theory and Practice of Ventilating Coal Mines"	·12381	·010000	·001923	·00189	·000445716	·0000360000	·0000069230	·0000000010000
15	*D. Murgue.* Normal and straight arched gangways.....	·02159	·001743	·000335	·00033	·000077724	·0000062748	·0000120669	·0000000001743
16	Straight gangways with rock walls and roof of normal or more than normal area.	·06152	·004965	·000954	·00094	·000221472	·0000178740	·0000343731	·0000000004965
17	Normal timbered passages....	·10209	·008242	·001585	·00156	·000367524	·0000296712	·0000570600	·0000000008242

II. Table showing the pressure per square foot in pounds due to the flow of air at different velocities in roads of different dimensions, as stated below, for a length of one mile, reckoning the co-efficient at ·00000001 lb. per square foot for a velocity of of one foot per minute.

Size of square road.	Diameter of round road.	Velocity one foot per second.	Velocity five feet per second.	Velocity ten feet per second.
ft. ft.	ft.	lbs.	lbs.	lbs.
1 x 1	1	·7603	19·00	76·03
2 x 2	2	·3801	9·50	38·01
3 x 3	3	·2534	6·33	25·34
4 x 4	4	·1900	4·75	19·00
5 x 5	5	·1520	3·80	15·20
6 x 6	6	·1267	3·16	12·67
7 x 7	7	·1086	2·71	10·86
8 x 8	8	·0954	2·38	9·54
9 x 9	9	·0844	2·11	8·44
10 x 10	10	·0760	1·90	7·60
11 x 11	11	·0691	1·72	6·91
12 x 12	12	·0633	1·58	6·33
13 x 13	13	·0584	1·46	5·84
14 x 14	14	·0543	1·35	5·43

III. Table showing the quantity of air that will flow through a passage one foot area, at different velocities, and the pressure due to a length of one mile, reckoning the co-efficient of friction at ·00000001 lb. per square foot for a velocity of one foot per minute.

Velocity in feet per second.	Cubic feet per minute.	Pressure per square foot in lbs.
1	60	·76
2	120	3·04
3	180	6·84
4	240	12·16
5	300	19·00
6	360	27·36
7	420	37·24
8	480	48·64
9	540	61·56
10	600	76·03

IV. Table showing length of roads offering resistance equal to one inch of water-gauge, of the dimensions below mentioned.

$k = \cdot00000001$ lb. per sq. ft. for a velocity of one foot per minute.

$v = 5$ ft. per second $= 300$ feet per minute.

Rule, $\dfrac{p\ a}{k\ v^2\ o} = l$ in feet.

Square Roads.			Round Roads.			Length of road in yards.
Dimensions of Road.	a	o	Dia. of Road.	Area.	Circumference or o.	
ft. ft.						
1 x 1	1	4	1	·7854	3·1416	481
2 x 2	4	8	2	3·141	6·2832	962
3 x 3	9	12	3	7·068	9·4248	1444
4 x 4	16	16	4	12·566	12·5664	1926
5 x 5	25	20	5	19·635	15·7080	2407
6 x 6	36	24	6	28·274	18·8496	2888
7 x 7	49	28	7	38·484	21·9912	3370
8 x 8	64	32	8	50·265	25·1328	3850
9 x 9	81	36	9	63·617	28·2744	4333
10 x 10	100	40	10	78·540	31·4160	4814
11 x 11	121	44	11	95·033	34·5576	5296
12 x 12	144	48	12	113·097	37·6992	5777
13 x 13	169	52	13	132·732	40·8408	6259
14 x 14	196	56	14	153·938	43·9826	6741

V. Table showing the water-gauge due to 30,000 cubic feet of of air passing through mines with the following equivalent orifices.

Rule, $w = 0{\cdot}1369 \times \left(\frac{Q}{A}\right)^2$

Q = quantity in thousands of cubic feet per minute.

Equivalent orifice in square feet.	Water-gauge in inches.	Equivalent orifice in square feet.	Water-gauge in inches.
3	13·69	15	·548
4	7·698	16	·481
5	4·928	17	·425
6	3·422	18	·379
7	2·513	19	·341
8	1·925	20	·308
9	1·521	21	·280
10	1·232	22	·254
11	1·018	23	·233
12	·856	24	·214
13	·728	25	·197
14	·627	26	·182

VI. Table of the values of the theoretical depression expressed in inches of water-gauge and head of air in feet.—(See Rules and Formulæ XIII., Chap. IV.)

Speed in feet of the periphery per second.	Depression in feet of air column.	Depression in inches of water-guage.	Speed in feet of the periphery per second.	Depression in feet of air column.	Depression in inches of water-gauge.
v	M	w	v	M	w
	$\frac{v^2}{32{\cdot}2}$	$\frac{M}{68}$		$\frac{v^2}{32{\cdot}2}$	$\frac{M}{68}$
30	27·95	0·411	75	174·69	2·569
35	38·04	0·559	80	198·75	2·922
40	49·69	0·731	85	224·38	3·299
45	62·82	0·924	90	251·55	3·699
50	77·63	1·141	95	280·28	4·122
55	93·94	1·381	100	310·55	4·567
60	111·80	1·644	105	342·39	5·035
65	131·18	1·929	110	375·77	5·526
70	152·17	2·238	115	410·71	6·039

VII. Table of the Elementary and Compound Gases, with their properties.

No.	Name of Gas.	Symbol.	Molecular weight H = 2.	Atomic weight.	Specific Gravity Air = 1.
1	Hydrogen	H	2	1	·06926
2	Light carbureted hydrogen, marsh gas or methyl hydride	$C H_4$	16	8	·5592
3	Ammonia	$N H_3$	17	8·505	·586
4	Watery vapor or water gas	$H_2 O$	18	9	·6235
5	Carbon	C	24	12	·832
6	Carbonic oxide or carbon monoxide	C O	28	14	·9678
7	Nitrogen	N	28	14	·9713
8	Heavy carbureted hydrogen, or olefiant gas, or ethylene	$C_2 H_4$	28	14	·9784
9	Air				1·
10	Nitric oxide	N O	60	15	1·039
11	Oxygen	O	32	16	1·1056
12	Sulphureted hydrogen	$H_2 S$	34	17	1·1748
13	Nitrous oxide	$N_2 O$	44	22	1·527
14	Carbonic acid or carbon dioxide	$C O_2$	44	22	1·529
15	Sulphur	S	64	32	1·95
16	Sulphurous acid	$S O_2$	64	32	2·247

VIII. Table of the weight of a cubic foot of air, in decimals of a pound avoirdupois, at different temperatures, calculated from the rule,

$$W = \frac{1{\cdot}3253 \times 30}{459 + t}.$$

Temperature t.	Weight in decimals of a lb.	Temperature t.	Weight in decimals of a lb.
32	·0809749	120	·0686678
35	·0804831	125	·0680799
40	·0796767	130	·0675020
45	·0788863	135	·0669338
50	·0781113	140	·0663751
55	·0773515	145	·0658256
60	·0766063	150	·0652852
62	·0763122	155	·0647535
65	·0758753	160	·0642305
70	·0751582	165	·0637158
75	·0744544	170	·0632093
80	·0737638	175	·0627108
85	·0730858	180	·0622201
90	·0724202	185	·0617371
95	·0717666	190	·0612614
100	·0711246	195	·0607931
105	·0704941	200	·0603318
110	·0698746	205	·0598775
115	·0692660	212	·0592529

IX. Table showing the comparative composition of Lignite, Bituminous Coal and Anthracite.

	Lignite.	Bituminous Coal.	Anthracite.
	Per Cent.	Per Cent.	Per Cent.
Carbon	66·32	78·57	90·39
Hydrogen	5·63	5·29	3·28
Nitrogen	0·56	1·84	0·83
Oxygen	22·86	12·88	2·98
Sulphur	2·36	0·39	0·91
Ash	2·27	1·03	1·61
Total	100	100	100
Weight of a cubic foot in lbs.	70	80	90

As a comparison the following percentages may be taken as representing the average chemical composition of wood and peat.

	Ligneous Fibre.	Peat.
Carbon	50	59
Hydrogen	6	6
Oxygen	43	33
Nitrogen	1	2
Total	100	100

X. Table to show the Square Root of Water-gauge Readings and Pressures.

Water-gauge in inches.	Square root of Water-gauge.	Pressure in lbs. per sq. ft.	Water-gauge in inches.	Square root of Water-gauge.	Pressure in lbs. per sq. ft.	Water-gauge in inches.	Square root of Water-gauge.	Pressure in lbs. per sq. ft.
·25	·50	1·30	2·25	1·500	11·70	4·25	2·061	22·10
·30	·548	1·56	2·30	1·516	11·96	4·30	2·073	22·36
·35	·592	1·82	2·35	1·532	12.22	4·35	2·085	22·62
·40	·611	2·08	2·40	1·549	12·48	4·40	2·097	22·88
·45	·678	2·34	2·45	1·565	12·74	4·45	2·109	23·14
·50	·707	2·60	2·50	1·581	13·00	4·50	2·121	23·40
·55	·741	2·86	2·55	1·596	13·26	4·55	2·133	23·66
·60	·774	3·12	2·60	1·612	13·52	4·60	2·144	23·92
·65	·800	3·38	2·65	1·627	13·78	4·65	2·156	24·18
·70	·836	3·64	2·70	1·643	13·94	4·70	2·167	24·44
·75	·866	3·90	2·75	1·658	14·20	4·75	2·179	24·70
·80	·894	4·16	2·80	1·673	14·56	4·80	2·190	24·96
·85	·922	4·42	2·85	1·688	14·82	4·85	2·202	25·22
·90	·949	4·68	2·90	1·702	15·08	4·90	2·213	25·48
·95	·974	4·94	2·95	1·717	15·34	4·95	2·224	25·74
1·00	1·000	5·20	3·00	1·732	15·60	5·00	2·236	26·00
1·25	1·118	6·50	3·25	1·802	16·90	5·25	2·291	27·30
1·30	1·141	6·76	3·30	1·816	17·16	5·30	2·302	27·56
1·35	1·164	7·02	3·35	1·830	17.42	5·35	2·313	27·82
1·40	1·182	7·28	3·40	1·843	17·68	5·40	2·323	28·08
1·45	1·204	7·54	3·45	1·857	17·94	5·45	2·334	28·34
1·50	1·224	7·80	3·50	1·870	18·20	5·50	2·345	28·60
1·55	1·245	8·06	3·55	1·884	18·46	5·55	2·355	28·86
1·60	1·264	8·32	3·60	1·897	18·72	5·60	2·366	29·12
1·65	1·284	8·58	3·65	1·910	18·98	5·65	2·377	29·38
1·70	1·303	8·84	3·70	1·923	19·24	5·70	2·387	29·64
1·75	1·322	9·10	3·75	1·936	19·50	5·75	2·397	29·90
1·80	1·341	9·36	3·80	1·949	19·76	5·80	2·408	30·16
1·85	1·360	9·62	3·85	1·962	20·02	5·85	2·418	30·42
1·90	1.378	9·88	3·90	1·974	20·28	5·90	2·428	30·68
1·95	1·396	10·14	3·95	1·987	20·54	5·95	2·439	30·94
2·00	1·414	10·40	4·00	2·000	20·80	6·00	2·449	31·20

XI. Table of the Volume, Density and Pressure of Air at various temperatures.

(Calculated from the following data: *Volume* of 1 lb. of air at constant atmospheric pressure = 14·7 lbs. per square inch, volume at 62 degrees Fahr. being 1; the *density* or weight is that of a cubic foot of air at atmospheric pressure, the *pressure* is that of a given weight of air having a constant volume, atmospheric pressure at 60 degrees Fahr. being 1.)

Fahr.	Volume.		Density lbs.	Pressure.	
	Cubic feet.	Comparative vol.		lbs. per sq. in.	Comparative pres.
0	11·583	·881	·086331	12·96	·881
32	12·387	·943	·080728	13·86	·943
40	12·586	·958	·079439	14·08	·958
50	12·840	·977	·077884	14·36	·977
62	13·141	1·000	·076097	14·70	1·000
70	13·342	1·015	·074950	14·92	1·015
80	13·593	1·034	·073565	15·21	1·034
90	13·845	1·054	·072230	15·49	1·054
100	14·096	1·073	·070942	15·77	1·073
110	14·344	1·092	·069721	16·05	1·092
120	14·592	1·111	·068500	16·33	1·111
130	14·846	1·130	·067361	16·61	1·130
140	15·100	1·149	·066221	16·89	1·149
150	15·351	1·168	·065155	17·19	1·168
160	15·603	1·187	·064088	17·50	1·187
170	15·854	1·206	·063089	17·76	1·206
180	16·106	1·226	·062090	18·02	1·226
200	16·606	1·264	·060210	18·58	1·264
210	16·860	1·283	·059313	18·86	1·283
212	16·910	1·287	·059135	18·92	1·287

(D. K. Clark.)

XII. Table showing the relative variations in mercury, water and gas, by changes of atmospheric pressure.

Column of		
Mercury.	Water.	Carbureted Hydrogen.
A.	B.	C.
	$\frac{A \times 848{\cdot}102}{62{\cdot}355}$	$A \times \frac{848{\cdot}102}{{\cdot}42553}$
$\frac{1}{2}$	6·80	9,965
1	13.60	19,930
$1\frac{1}{2}$	20·40	29,895
2	27·20	39,860
$2\frac{1}{2}$	34·00	49,826
3	40·80	59,791

XIII. Table showing the Pressure of the atmosphere per square inch and per square foot, at the following Readings of the Barometer.

(Rule.—Barometer in inches × ·4908 = pressure per square inch; pressure per square inch × 144 = pressure per square foot.)

Barometer in inches.	Pressure per square inch in pounds.	Pressure per square foot in pounds, decimals omitted.
28·00	13·74	1978
28·25	13·86	1995
28·50	13·98	2013
28·75	14·11	2031
29·00	14·23	2049
29·25	14·35	2066
29·50	14·47	2083
29·75	14·60	2102
30·00	14·72	2119
30·25	14·84	2136
30·50	14·96	2154
30·75	15·09	2172
31·00	15.21	2190

XIV. Table to Illustrate the Chemical Change which takes place in Breathing.

(The air inhaled has the common temperature of the atmosphere, on an average about 59° F. The air exhaled has the temperature of the body, about 99 degrees Fahr. and contains a corresponding quantity of aqueous vapor, which amounts at each exhalation to from 1 to 1½ grains.)

Amount present in air of	Air inhaled.		Air exhaled.	
	In 100 vols. by measure.	In 100 parts by weight.	In 100 vols. by measure.	In 100 parts by weight.
Oxygen	20·815	23·009	16·033	17·373
Nitrogen	79·185	76·991	79·587	76·081
Carbonic acid	trace.	trace.	4·380	6.546
	100.	100.	100.	100.

XV. Table of Analyses of Different Compound Gases, by weight.

	Carbonic Oxide Gas. C O	Carbonic Acid Gas. $C O_2$
Carbon	42·86	27·27
Oxygen	57·14	72·73
Total	100.	100.

	Marsh Gas. $C H_4$	Olefiant Gas. $C_2 H_4$
Carbon	74·95	85·68
Hydrogen	25·05	14·32
Total	100.	100.

Air.

Oxygen	23.00
Nitrogen	77.
	100.

Sulphureted Hydrogen.
$H_2 S$

Sulphur	94·12
Hydrogen	5·88
	100.

XVI. Table of Analyses of Coal Gas from Cannel Coal.

	Manchester gas. (1)	Manchester gas. (2)	Rochdale gas.	London gas.	Cardiff gas.
Hydrogen	45·58	52·71	53·44	35·94	39·69
Marsh Gas	34·90	31·05	29·87	41·99	36·27
Carbon monoxide (carbonic oxide)	6·64	4·47	5·86	10·07	9·33
Olefines	6·46	11·19	10·83	10·81	8·95
Nitrogen	2·46				2·94
Carbon dioxide (carbonic acid)	3·67	0·58		1·19	2·49
Oxygen					·33
Sulphureted hydrogen	0·29				
Total	100.	100.	100.	100.	100.

XVII. Table of Analyses of Coal Gas from Bituminous Coal.

	London gas. (1)	London gas. (2)	Heidelberg gas.	Cardiff gas.
Hydrogen	50·05	51·24	44·00	47·32
Marsh Gas	32·87	35·28	38·40	38·21
Carbon monoxide (carbonic oxide)	12·89	7·40	5·73	7·79
Olefines	3·87	3·56	7·27	4·41
Nitrogen		2·24		1·83
Carbon dioxide (carbonic acid)	0·32	0·28	4·23	0·13
Oxygen			0·37	·31
Total	100.	100.	100.	100.

XVIII. Table of the Expansion of Air by Heat. (By Magnus and Regnault.)

Degs. Fahr.	Volume.	Degs. Fahr.	Volume.
32	10,000	130	11,996
40	10,160	140	12,199
50	10,366	150	12,403
60	10,570	160	12,606
70	10,773	170	12,810
80	10,977	180	13,014
90	11,181	190	13,218
100	11,385	200	13,421
110	11,588	210	13,625
120	11,792	212	13,666

And the volume of any other temperature, t, will be

$$10{,}000 \times \frac{459 + t}{459 + 32}.$$

XIX. Table showing the pressure of air in shafts, in pounds avoirdupois, per square foot of area, at the following depths and temperatures.

Degs. Fahr.	DEPTH FROM SURFACE.								
	100 feet.	300 feet.	600 feet.	900 feet.	1200 feet.	1500 feet.	1800 feet.	2100 feet.	2400 feet.
40	7·967	23·903	47·806	71·709	95·612	119·515	143·418	167·321	191·224
45	7·888	23·665	47·321	70·997	94·663	118·329	141·995	165·661	189·327
50	7·811	23·433	46·866	70·300	93·733	117·166	140·600	164·033	187·467
55	7·735	23·205	46·410	69·616	92·821	116·027	139·232	162·438	185·643
60	7·660	22·981	45·963	68·945	91·927	114·909	137·891	160·873	183·855
65	7·587	22·762	45·525	68·287	91·050	113·812	136·575	159·338	182·100
70	7·515	22·547	45·094	67·642	90·189	112·737	135·284	157·832	180·379
75	7·445	22·336	44·672	67·008	89·345	111·681	134·017	156·354	178·690
80	7·376	22·129	44·258	66·387	88·516	110·645	132·774	154·903	177·033
85	7·308	21·925	43·851	65·777	87·702	109·628	131·556	153·480	175·405
90	7·242	21·726	43·452	65·178	86·904	108·630	130·356	152·082	173·808
95	7·176	21·529	43·059	64·589	86·119	107·649	129·179	150·709	172·239
100	7·112	21·337	42·676	64·012	85·349	106·686	128·024	149·361	170·699
105	7·049	21·148	42·296	63·444	84·592	105·741	126·889	148·037	169·185
110	6·987	20·962	41·924	62·887	83·849	104·811	125·774	146·736	167·699
115	6·926	20·779	41·559	62·339	83·119	103·899	124·678	145·458	166·238
120	6·866	20·600	41·200	61·801	82·401	103·001	123·602	144·202	164·802
125	6·807	20·423	40·846	61·271	81·695	102·119	122·543	142·967	163·391
130	6·750	20·250	40·501	60·751	81·002	101·253	121·503	141·754	162·004
135	6·693	20·080	40·160	60·240	80·320	100·400	120·480	140·560	160·645
140	6·637	19·912	39·825	59·737	79·650	99·562	119·475	139·387	159·300
145	6·582	19·747	39·495	59·243	78·990	98·738	118·486	138·233	157·981
150	6·528	19·585	39·171	58·756	78·342	97·927	117·513	137·098	156·684
155	6·475	19·426	38·852	58·278	77·704	97·130	116·556	135·982	155·408
160	6·423	19·269	38·538	57·807	77·076	96·345	115·614	134·884	154·153
165	6·371	19·114	38·229	57·344	76·458	95·573	114·688	133·803	152·917
170	6·320	18·962	37·925	56·888	75·851	94·813	113·776	132·739	151·702
175	6·271	18·813	37·626	56·439	75·252	94·066	112·879	131·692	150·505
180	6·222	18·666	37·332	55·998	74·664	93·330	111·996	130·662	149·328
185	6·173	18·521	37·042	55·563	74·084	92·605	111·126	129·647	148·169
190	6·126	18·378	36·756	55·135	73·513	91·892	110·270	128·648	147·027
195	6·079	18·237	36·475	54·713	72·951	91·189	109·427	127·665	145·903
200	6·033	18·099	36·199	54·298	72·398	90·497	108·597	126·696	144·797

XX. Table showing barometric readings corresponding with different altitudes, in French and English measures.

Altitude. Meters.	Reading of barometer. m. m.	Altitude. Feet.	Reading of barometer. Inches.	Altitude. Meters.	Reading of barometer. m. m.	Altitude. Feet.	Reading of barometer. Inches.
0	762	0·	30·	1147	660	3763·2	25·98
21	760	68·9	29·92	1269	650	4163·3	25·59
127	750	416·7	29·52	1393	640	4568·3	25·19
234	740	767·7	29·13	1519	630	4983·1	24·80
342	730	1122·1	28·74	1647	620	5403·2	24·41
453	720	1486·2	28·35	1777	610	5830·2	24·01
564	710	1850·4	27·95	1909	600	6243·	23·62
678	700	2224·5	27·55	2043	590	6702·9	23·22
793	690	2599·7	27·16	2180	580	7152·4	22·83
909	680	2962·1	26·77	2318	570	7605·1	22·44
1027	670	3369·5	26·38	2460	560	8071·	22·04

1 meter = 3·2808992 feet = 39·3707904 inches.

XXI. Table of comparative readings of thermometer on the different scales—Centigrade, Réaumur and Fahrenheit.

C	R	F	C	R	F	C	R	F	C	R	F
100	80·	212·	75	60·	167·	50	40·	122·	25	20·	77·
99	79·2	210·2	74	59·2	165·2	49	39·2	120·2	24	19·2	75·2
98	78·4	208·4	73	58·4	163·4	48	38·4	118·4	23	18·4	73·4
97	77·6	206·6	72	57·6	161·6	47	37·6	116·6	22	17·6	71·6
96	76·8	204·8	71	56·8	159·8	46	36·8	114·8	21	16·8	69·8
95	76·	203·	70	56·	158·	45	36·	113·	20	16·	68·
94	75·2	201·2	69	55·2	156·2	44	35·2	111·2	19	15·2	66·2
93	74·4	199·4	68	54·4	154·4	43	34·4	109·4	18	14·4	64·4
92	73·6	197·6	67	53·6	152·6	42	33·6	107·6	17	13·6	62·6
91	72·8	195·8	66	52·8	150·8	41	32·8	105·8	16	12·8	60·8
90	72·	194·	65	52·	149·	40	32·	104·	15	12·	59·
89	71·2	192·2	64	51·2	147·2	39	31·2	102·2	14	11·2	57·2
88	70·1	190·4	63	50·4	145·4	38	30·4	100·4	13	10·4	55·4
87	69·6	188·6	62	49·6	143·6	37	29·6	98·6	12	9·6	53·6
86	68·8	186·8	61	48·8	141·8	36	28·8	96·8	11	8·8	51·8
85	68·	185·	60	48·	140·	35	28·	95·	10	8·	50·
84	67·2	183·2	59	47·2	138·2	34	27·2	93·2	9	7·2	48·2
83	66·4	181·4	58	46·4	136·4	33	26·4	91·4	8	6·4	46·4
82	65·6	179·6	57	45·6	134·6	32	25·6	89·6	7	5·6	44·6
81	64·8	177·8	56	44·8	132·8	31	24·8	87·8	6	4·8	42·8
80	64·0	176·	55	44·	131·	30	24·	86·	5	4·	41·
79	63·2	174·2	54	43·2	129·2	29	23·2	84·2	4	3·2	39·2
78	62·4	172·4	53	42·4	127·4	28	22·4	82·4	3	2·4	37·4
77	61·6	170·6	52	41·6	125·6	27	21·6	80·6	2	1·6	35·6
76	60·8	168·8	51	40·8	123·8	26	20·8	78·8	1	0·8	33·8

XXII. Table of velocities and pressures of Air.

Let P = pressure of air in pounds per square foot.
Let V = velocity in miles per hour.

$$\text{Then } P = \frac{V^2}{200}$$

Miles per hour.	Feet per second.	Pounds per square foot.	Miles per hour.	Feet per second.	Pounds per square foot.	Miles per hour.	Feet per second.	Pounds per square foot.
1	1·46	·005	18	26·40	1·620	35	51·33	6·125
2	2·93	·020	19	27·86	1·805	36	52·80	6·480
3	4·40	·045	20	29·33	2·000	37	54·26	6·845
4	5·86	·080	21	30·80	2·205	38	55·73	7·220
5	7·33	·125	22	32·26	2·420	39	57·20	7·605
6	8·80	·160	23	33·73	2·645	40	58·66	8·000
7	10·26	·245	24	35·20	2·880	41	60·13	8·405
8	11·73	·320	25	36·66	3·125	42	61·60	8·820
9	13·20	·405	26	38·13	3·380	43	63·06	9·245
10	14·66	·500	27	39·60	3·645	44	64·53	9·680
11	16·13	·605	28	41·06	3·920	45	66·00	10·125
12	17·60	·720	29	42·53	4·205	46	67·46	10·580
13	19·06	·845	30	44·00	4·500	47	68·93	11·045
14	20·53	·980	31	45·46	4·805	48	70·40	11·520
15	22·00	1·125	32	46·93	5·140	49	71·86	12·005
16	23·46	1·280	33	48·40	5·445	50	73·33	12·500
17	24·93	1·445	34	49·86	5·780	60	88·00	18·000

XXIII. Table showing the quantity of gas in cubic feet obtained from coal.

Locality where Coal is mined.	Specific Gravity of Gas.	Cubic feet of gas obtained per ton of Coal.	Weight in pounds of gas per ton of Coal.
Boghead	·752	15,000	866
Capeldrae	·577	14,400	638
Lesmahagow	·618	13,200	627
Arniston	·626	12,600	606
Newcastle-on-Tyne	·475	11,648	423
South Wales	·737	11,424	645
Pelaw	·444	11,424	389
Pelton	·437	11,424	387
Bickerstaff	·475	11,424	415
Wigan	·528	11,400	461
Garesfield	·398	10,500	321
Powell's South Wales	·459	10,165	357
Forest of Dean	·360	10,133	279
S. Staffordshire	·320	9,600	235
Derby Deep Main	·424	9,400	308
Derby Soft Coal	·528	7,500	303
Leeds	·530	6,500	264

XXIV. Table Showing the Conversion of Column of Water to Column of Mercury and Fire-damp.

Water.	Mercury.	Fire-damp.
1	0·0738	1,465
2	0·1474	2,930
3	0·2211	4,395
4	0·2948	5,861
5	0·3685	7,327
6	0·4421	8,792
7	0·5158	10,258
8	0·5895	11,723
9	0·6632	13,189

XXV. Table showing the relative weight of water and air at various temperatures, with deductions made therefrom.

Temperature F.	Weight of a cubic foot of water in lbs.	Pressure per sq. ft. in lbs. represented by 1 in. of water-gauge.	Weight of a cubic foot of air in lbs.	Proportion or weight of water; air being 1.	Motive column or head of air in feet equal to one inch of water-gauge.	Constant for finding equivalent orifice in Formulæ XII., Chapter IV.	Constant for finding water-gauge in Formulæ XII., Chapter IV.
I.	II.	III. = $\frac{\text{II.}}{12}$	IV. = $\frac{39{\cdot}7587}{459 + t}$	V. = $\frac{\text{II.}}{\text{IV.}}$	VI. = $\frac{\text{V.}}{12}$	VII. = $\frac{1}{\sqrt{64{\cdot}4 \times \text{VI} \times 60 \times {\cdot}65}} \div 1000.$	VIII. = VII^2
32	62·417	5·20	·0809749	770·8	64·2	·398	·1584
40	62·423	5·20	·0796767	783·4	65·3	·395	·1560
50	62·409	5·20	·0781113	798·9	66·5	·391	·1528
60	62·367	5·19	·0766063	814·1	67·8	·388	·1505
62	62·355	5·19	·0763122	817·1	68·1	·387	·1497
70	62·302	5·19	·0751582	828·9	69·0	·384	·1474
80	62·218	5·19	·0737638	843·5	70·3	·381	·1451
90	62·119	5·18	·0724202	857·7	71·5	·377	·1421
100	62·022	5·17	·0711246	872·0	72·6	·375	·1406
110	61·868	5·16	·0698746	885·4	73.8	·372	·1383
120	61·715	5·14	·0686678	898·7	74·9	·369	·1361
130	61·563	5·13	·0675020	912·0	76·0	·366	·1339

CHAPTER VI.

LEGISLATION ON THE SUBJECT OF MINE VENTILATION IN THE UNITED STATES AND FOREIGN COUNTRIES.

In order to have an intelligent comprehension of the whole question of mine ventilation, it appears desirable, indeed necessary, to review, at least briefly, some of the laws which have been enacted in different countries on the subject for the protection of miners from dangers associated with the noxious gases which so commonly pervade the atmosphere of coal mines. By doing this the reader will see how the matter has been considered by the mining authorities of different coal producing countries.

The legislators of those countries where coal mining is carried on extensively have acted wisely and humanely in enacting laws for the safety of those engaged in the operations.

In making extracts from the various mining laws, we will limit their extent as much as possible, and only make reference to matters that may be considered of essential importance.

Prussia.

We will first give some particulars with regard to Prussia, where the section of the air-ways is dependent upon the quantities of air necessary for the ventilation of the whole mine, including different splits, calculated upon a velocity of 13 feet per second for the fresh air-current, and of 22 feet per second for the return air-current.

The ventilation of fire-damp mines must be sufficient to prevent the accumulation of fire-damp under ordinary circumstances, and to keep all parts of the mine constantly in a safe condition to be entered and worked.

Special ventilation plans are to be prepared in fire-damp mines. The use of ventilating furnaces is permitted only on condition that the furnace be fed with fresh air. The quantity of fresh air per minute is to be at least 2 cubic meters = 71 cubic feet per minute for each man of the largest force working underground, and a horse is counted to be equal to four men.

All fire-damp mines must have stations for the measurement of the air-currents. Such stations to be given on the working plan and on the ventilation plan of the mine. Air-doors are to be self closing. The Prussian Fire-Damp Commission in their report on the ventilation of fiery mines recommend the ascensional principle of ventilation and say: "The ventilation should be managed in such a way that the current of fresh air descends from the surface by the shortest way, until it reaches the level of the working vein, and afterwards each current should flow in an upward direction through the different sections of the mine."

England.

As regards the mining laws of England we may allow ourselves to quote Professor Arthur Lakes, who has recently returned from a visit to that country, and who in the *Mining Industry* for Nov. 30th, 1893, says: "There is no class of men in the world so protected by law as the English coal miner." A good many Englishmen are of the opinion that coal operations are over-legislated, but although English mine superintendents have regarded mining legislation as unnecessarily particular—perplexing, and harassing—yet there can be no doubt the effect of it in recent years has been to minimize the dangers of coal mining, especially under the head of colliery explosions. In England the law requires that "an adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless noxious gases to such an extent that the working places of the shafts, levels, stables, and workings of the mine, and the traveling roads to and from those working places, shall be in a fit state for working and passing therein. Now if this law was thoroughly carried out, there would be no explosions of fire-damp. No specified quantity of air is required by the act, but the first general rule as here quoted requires that it shall be *adequate*. The law with respect to the construction and use of safety lamps is very strict and explicit, and so it is with regard to the use of explosives in mining. The framers of this act seem to have attached much importance to the changes of the weather for the law requires that a barometer and thermometer shall be placed above ground in a conspicuous position near the entrance to the mine.

Nova Scotia.

The mining law of Nova Scotia is copied in a great measure from that of England. The first general rule requires that "an adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless noxious gases, to such an extent that the working places of the shafts, levels, stables, winzes, sumps and workings of such mine, and the traveling roads to and from such working places, shall be in a fit state for working and passing therein. In every mine in which inflammable gas has been found within the preceding twelve months a competent person or persons holding certificates as underground managers, overmen, or shotfirers, who shall be appointed for the purpose, shall inspect with a safety lamp that part of the mine being or intended to be worked, and the roadways leading thereto, within five hours of the time of each shift commencing work, and if inflammable gas has been found within the preceding three months, then, within three hours of the time of commencing work, shall make a true report to the manager, undergroumd manager, or overman, at the time in

charge of the pit, of the condition thereof as far as ventilation is concerned; and a workman shall not go to work in such part until the same and the roadways leading thereto are stated to be safe." The law likewise lays down particular rules for the use of explosives in mines, and the shot-firer or fire-boss is required to pass an examination and be in possession of a certificate of competency before he is appointed to take charge of the blasting or shot-firing in a mine.

Victoria.

With regard to the ventilation of mines in Victoria, we find it stated in the General Reports of the Mining Inspectors for 1892, that the sooner the law fixes the amount of air per minute to be sent in for every man working in the mine, the better it will be for the employés.

In certain respects the laws of some of the States of America are in advance of those of other countries, and before closing this chapter we will give illustrations of some of the requirements of the law in different states of the Union.

Anthracite Law of Pennsylvania.

For example, with regard to furnaces, the Anthracite Law of Pennsylvania enacts that "It shall not be lawful to use a furnace for the purpose of ventilating any mine wherein explosive gases are generated."

Not more than 75 persons shall be employed at the same time in any one current or split of air.

The quantity of air shall not be less than 200 cubic feet a minute and in no case in mines generating explosive gas shall the velocity exceed 9 feet per second.

All ventilating doors shall fall-to of themselves.

Bituminous Law of Pennsylvania.

The Bituminous Law of Pennsylvania enacts that not less than 100 cubic feet of air per minute shall be provided for each person employed in a mine, but, where fire-damp has been detected, the minimum shall be 150 cubic feet per minute. Not more than 65 persons shall be allowed to work in one current. No accumulation of gas shall be allowed to exist in the worked out parts of a mine.

The Davy and Clanny lamps are prohibited for general work unless protected by a metallic shield. The lamps used shall be the property of the operator.

Ohio.

In the State of Ohio the amount of ventilation to be provided shall not be less than 100 cubic feet per minute for each person employed. All mines generating fire-damp shall be kept free from standing gas.

Iowa.

The quantity of air to be provided for the mines in the State of Iowa shall be not less than 100 cubic feet per minute for each person employed, and 500 cubic feet per minute for each mule.

Washington.

In the State of Washington the amount of air in circulation in coal mines shall in no case be less than 100 cubic feet for each person per minute.

Tennessee.

In the State of Tennessee it is enacted that an adequate amount of ventilation, not less than fifty-five cubic feet per second of pure air, or thirty-three hundred cubic feet per minute for every fifty men at work in the mine shall be provided. The intake air-way shall not be less than 20 square feet area and the return air-way not less than 25 square feet.

West Virginia.

In West Virginia ample means of ventilation shall be provided affording not less than 100 cubic feet of air per minute for each and every person employed in the mine.

Kentucky.

The law of the State of Kentucky requires that all mines shall be kept free of standing gas, and the quantity of air to be provided shall not be less than 100 cubic feet per man per minute.

Alabama.

In the State of Alabama there shall be provided sufficient ventilation for each and every person employed in the mine, which shall be circulated around the main headings, cross-headings, and working places to an extent that will dilute, render harmless and carry off noxious and dangerous gases generated therein.

Kansas.

The air to be provided in the coal mines of Kansas is 100 cubic feet per minute per person in veins 3 feet thick or over. The mines are to be kept free of standing gas. Shotfirers are to be appointed, whose duty it will be to fire shots once a day, when the mines are in operation. The coal shall be properly undermined before the shots are fired.

Arkansas.

According to the law of the State of Arkansas the amount of air to be provided is not less than 100 cubic feet per man, per minute.

A bore-hole is to be kept 20 feet in advance of the face of a working place going towards an abandoned mine suspected of containing inflammable gas or water.

Indiana.

In the State of Indiana there shall be provided a sufficient amount of ventilation affording not less than 100 cubic feet per minute for each and every person employed and 300 cubic feet per minute for each mule, horse or other animal used in the mine. The air currents shall be split so as to give separate currents to at least every 50 persons at work.

Territories.

In the mines of the Territories of the United States, an adequate amount of ventilation shall be provided, not less than 55 cubic feet of pure air per second or 3,300 cubic feet per minute for every 50 men at work. In no case shall a furnace shaft be used as, or for the purposes of this act, be deemed an escape-shaft.

APPENDIX.

QUESTIONS AND ANSWERS ON SUBJECTS RELATING TO MINE VENTILATION, ATMOSPHERIC AIR AND GASES, MAINLY SELECTED FROM VARIOUS AMERICAN EXAMINATIONS FOR MINE INSPECTORS AND MINE FOREMEN.

1. What is meant by the area of an air course?

ANS. It means the superficies or number of square units—usually feet—contained in the section of a road.

2. What is meant by the section of a road?

ANS. A cross-cut made at right angles to its plane.

3. What is meant by the perimeter of a road?

ANS. The circumference or measure of the outline of the section.

4. What is meant by the rubbing surface of a road?

ANS. The superficial area of the walls—that is the sides, roof and floor—usually reckoned in square feet, and is calculated by multiplying the perimeter by the length.

5. What is the perimeter of a road 6 feet high and 7 feet wide?

ANS. $6 + 6 + 7 + 7 = 26$.

6. What is the area of a road measuring 7 feet 3 inches by 6 feet 6 inches?

ANS. By cross-multiplication,

′	″	
7	3	
6	6	
3	7	6
43	6	
47	1	6 = $47\frac{1}{8}$ feet.

By decimals,

7·25
6·5
3625
4350
47·125 = $47\frac{1}{8}$ feet.

7. What is the rubbing surface of a road 8 feet 6 inches wide, 6 feet 9 inches high and 3000 feet long?

ANS. 8 ft. 6 in. + 8 ft. 6 in. + 6 ft. 9 in. + 6 ft. 9 in. = 30 ft. 6 in. the perimeter and this multiplied by 3000, the length = 91,500 sq. ft. the rubbing surface,

8. How is the quantity of air passing along an underground road ascertained?

Ans. By observing with an anemometer the velocity of the flow of the current, by measuring the area of the section of the road, and multiplying the two together.

9. If the velocity of the air be 375 ft. a minute, and the road has an area of 48 ft. what is the quantity of air passing?

Ans. $375 \times 48 = 18{,}000$ cubic feet per minute.

10. If the velocity of the air in an upcast shaft 14 ft. diameter be 1,100 feet a minute, how much air is there returning from the mine?

Ans. The area of the shaft is found by squaring the diameter and multiplying by ·7854; $14 \times 14 \times \cdot7854 = 153\cdot9384$ area, then $153\cdot9384 \times 1{,}100 = 169{,}332$ cubic feet of air per minute.

11. If with a water-gauge of half an inch the quantity of air passing be 24,000 cubic feet, how much will pass when the water-gauge reads 3 inches?

Ans. The quantity is according to the square root of the pressure, or the water-gauge. By Table X. of Chap. V. it will be seen that the square root of one-half = ·707, and the square root of 3 = 1·732; then say if ·707 gives 24,000, what will 1·732 give, thus $\frac{24{,}000 \times 1.732}{\cdot707} = 58{,}795$ cubic feet.

12. If air has a velocity of 550 feet a minute, how many miles an hour is it equal to?

Ans. There are 1,760 yards or 5,280 feet in a mile: the velocity of the air per hour will be $550 \times 60 = 33{,}000$ feet, then $\frac{33{,}000}{5{,}280} = 6\cdot25$ miles an hour.

13. If in furnace ventilation the downcast has a temperature of 65 degs., and the upcast 140 degs., the depth of the shafts being 1,500 feet, what is the pressure of the ventilation?

Ans. By reference to table XIX., Chap. V., it will be seen that the weight of air at 65 degs. at a depth of 1,500 feet will be 113·812 lbs., and at 140 degs. it will be 99·562 lbs.; the difference between these two is 14·25 lbs., which is the amount of the pressure.

14. If the water-gauge be 3½ in., what is the pressure per square foot?

Ans. $3\cdot5 \times 5\cdot2 = 18\ 2$ lbs.

15. If the quantity of air passing be 60,000 cubic feet a minute, and the water gauge be 2 inches, what is the amount of the horse-power producing the ventilation?

Ans. $\frac{60{,}000 \times 2 \times 5\cdot2}{33{,}000} = 19$ nearly.

16. What quantity of air will be necessary to ventilate a mine in which 200 men are engaged?

Ans. According to the Anthracite Mine Law of Pennsyl-

vania, 200 cubic feet of air per man per minute is the minimum quantity to be provided; the inspector of the 8th Anthracite district says in his report for 1892, that "most of the fiery mines require much larger volumes than the minimum quantity provided for in the Act of Assembly."

17. How much will the ventilating pressure have to be increased if the quantity of air be doubled?

ANS. Four times.

18. How much will the power have to be increased if the quantity be increased from 10,000 to 15,000?

ANS. According to the cube of $1\frac{1}{2} = 1{\cdot}5 \times 1{\cdot}5 \times 1{\cdot}5 = 3{\cdot}375$ times.

19. What is the horse-power required to drive a fan producing 60,000 cubic feet of air per minute, with a water-gauge of 1·7 in.? If the quantity be increased to 100,000 cubic feet per minute, how much additional power would be required?

ANS. The horse-power is found thus:

$$\frac{60{,}000 \times 1{\cdot}7 \times 5{\cdot}2}{33{,}000} = 16 \text{ horse-power.}$$

The power is according to the cube of the quantity, therefore, after canceling the noughts, the power will be increased from 6^3 to $10^3 = 216$ to 1,000 and $\frac{1{,}000}{216} = 4{\cdot}63$ times.

20. How much more resistance does an air-current encounter when traveling at 600 feet per minute than at 500 feet per minute, size of air-way being unchanged? If the water-gauge is ·76 inch at the lower speed, what would it be at the higher?

ANS. As the resistance is according to the square of the velocity, it would be in proportion to 5 squared and 6 squared = as 25 is to 36, which would be in proportion to these figures, thus:

$$25 : {\cdot}76 :: 36 = 1{\cdot}09.$$

21. Given an arched air-way 10 feet diameter, with semicircle arch, springing five feet from the floor, velocity of air 500 feet per minute, what will be the quantity of air in cubic feet per minute?

ANS. The area of the arch is found thus:

$$\frac{10 \times 10 \times {\cdot}7854}{2} = \quad 39{\cdot}27 \text{ ft.}$$

Below the springing, thus:

$$5 \times 10 = \quad \frac{50}{89{\cdot}27}$$

$89{\cdot}27 \times 500 = 44{,}635$ cubic feet per minute passing.

22. What is the comparative friction or resistance of the air when traveling at the same velocity through an air-course 8 feet square, and one 12 feet by 5 feet 4 in.?

ANS. The friction or resistance in this case will be according to the rubbing surface or perimeter; in the road 8 feet square, it will be 8 + 8 + 8 + 8 = 32; in the other road it will be 12 + 12 + 5 ft. 4 in. + 5 ft. 4 in. = 34 ft. 8 in. The friction will be in the proportion of 32 to 34⅔.

23. If a ventilating current of 27,500 cubic feet per minute is circulating in a mine with 1·8 in. water-gauge, what will the water-gauge be if the quantity of air is increased to 50,000 cubic feet per minute with same conditions in the mine?

ANS. The water-gauge will be according to the square of the quantities, thus:

$27{,}500^2 : 1{\cdot}8 :: 50{,}000^2 = 5{\cdot}9$ water-gauge.

24. How many cubic feet of air will pass per minute through an air course 5 ft. by 7 ft. when the current is traveling at the rate of 20 yards in 15 seconds?

ANS. 20 yards in 15 seconds will be equal to 80 yards in a minute: $80 \times 3 = 240$ ft.; $5 \times 7 = 35$, and $35 \times 240 = 8{,}400$ cubic feet per minute.

25. The velocity of the air is 9 feet per second, and the area of the road is 70 ft., what is the quantity of air passing?

ANS. $9 \times 60 \times 70 = 37{,}800$ cubic feet per minute.

26. If the air-road be doubled in length, how much will the resistance be increased?

ANS. It will be doubled.

27. If the ventilating pressure be indicated with a water-gauge of $\frac{8}{10}$ths of an inch, when the quantity of air passing is 20,000 cubic feet, what will the quantity be when, by additional appliances, the water-gauge is increased to 1½ inches?

ANS. The quantity will be in accordance with the square root of the water-gauge. $\frac{8}{10} = {\cdot}8$; $1\frac{1}{2} = 1{\cdot}5$. By referring to table X., Chap. V., it will be seen the square root of ·8 = ·894, and of 1·5 = 1·224. Then, as ·894 is to 20,000 so is 1·224 to 27,382 cubic feet per minute.

28. What is meant by dividing one current of air into two equal splits?

ANS. It means this: supposing there is one current of air going round the mine through a road 6 ft. square and 1,600 yards long, when divided into two equal splits there will be two roads each 800 yards long and 6 ft. square.

29. What are the advantages and disadvantages of a dumb-drift?

ANS. The advantage in using this slope drift is that the return air does not go over the furnace, and there is therefore no danger of an explosion thereby; the disadvantage is that the heated air column is not so long and consequently the ventilating pressure is less, and the air used to keep up the furnace is not utilized in the mine.

30. If a dumb-drift rise 35 per cent. for 70 yards, what height will it come out in the upcast shaft above the furnace?

ANS. It will come into the shaft at 28½ yds. above the furnace.

31. Suppose the shaft to be 300 yards deep, and the temperature in the upcast to be 200°, what pressure is lost by a dumb-drift coming into the upcast 22½ yards above the furnace?

ANS. The weight of air, by Table XIX., Chap. V., at a depth of 900 feet, at the temperature of 200° = 54·298 lbs. at the reduced depth it will be $\frac{900}{67{\cdot}5}$ of this = $\frac{52{\cdot}725}{1{\cdot}573}$ which is the amount of pressure lost under the conditions stated.

32. If the furnace be supplied with 3,000 feet of air per minute, what additional friction does it put on the air?

ANS. That depends on the quantity of air passing through the mine; the friction will be according to the square of the quantity. If 40,000 ft. go through the mine, 43,000 will go up the shaft; the friction will, therefore, be as 40^2 is to 43^2 or as 16 to $18\frac{1}{2}$.

33. What is the difference between natural and artificial ventilation?

ANS. By natural ventilation is meant the current produced naturally by the changes in temperature of the outer and inner air, or the air in and out of the mine. In ~~summer~~ winter the outer air will be colder than the air of the mine, so that it happens in shallow mines, where natural ventilation is used, the air at one time of the year will flow in one direction, and at other times in the opposite direction. Natural ventilation is thus uncertain and irregular. By artificial ventilation is meant the regular application of some motor to maintain an air-current, as by furnace or fan, by the working of which one end of the air-current is rarefied and a ventilating pressure produced.

34. Is furnace ventilation better in winter than in summer? If so, why?

ANS. It is better in winter, because the downcast air is colder and heavier in winter than in summer. The air of the mine is pretty constant all the year round; therefore, with the same amount of firing there will be a greater difference in the temperature of the two shafts in winter and consequently a greater pressure.

35. In using furnaces, which will give the largest ventilating pressure, deep or shallow shafts?

ANS. Deep shafts—the pressure being in accordance with the difference of temperature multiplied by the depth.

36. What is the extreme pressure in the ventilation that may be obtained by furnace and fan?

ANS. If in furnace ventilation we take the temperature of the air in the downcast to be 50 degs. and the upcast at 200 degs., by table VIII., Chap. V., it will be seen that the weight of a foot of air at

50 degs. = ·0781113 lb.
200 degs. = ·0603318 lb.
Difference = ·0177795 lb.

Then the pressure will be found to be at the following depths viz :

At 600 ft. = 10·66 lbs. per square foot.
At 1200 ft. = 21·33 lbs. per square foot.
At 1800 ft. = 32·00 lbs. per square foot.
At 2400 ft. = 42·67 lbs. per square foot.

The greatest pressure the writer has seen noted in the actual working of a fan is that at Prosper No. 1 Colliery, Westphalia, where 10·7 inches have been recorded, which is equal to a pressure of 55·64 lbs. per square foot.

37. Can a greater pressure be obtained in a large shaft than in a small one?

Ans. No, the ventilating pressure does not depend on the sizes of the shafts, for, as J. J. Atkinson says, "whatever may be the relative sizes of the shafts, the air in the one will balance that in the other if the density of the air is the same in each; this may be termed the pneumatic paradox."

38. What is meant by the pneumatic paradox?

Ans. It may be compared to the hydrostatic paradox, which means that the pressure on the bottom of a vessel full of liquid depends neither on the form of the vessel nor on the quantity of the liquid, but only on the height of the level of the liquid above the bottom; in the same way neither the size nor form of the air-shafts which act as the downcast or upcast respectively alter the pressure at the bottom of the pits. The pressure is obtained only by altering the density of the air in the two shafts.

39. In erecting a ventilating fan or furnace, what points should be considered with respect to safety?

Ans. The fan should be erected in such a position, and placed under such conditions as will tend to insure its being uninjured by an explosion; and in furnace ventilation, where there is inflammable gas, the furnace should be provided with a dumb-drift. These conditions are enforced by the 1887 Mining Act of Great Britain.

40. Are furnaces admissible in all cases for the ventilation of coal mines?

Ans. No. Their use is forbidden by the Anthracite Mining Law of Pennsylvania, for the purpose of ventilating any mine wherein explosive gases are generated.

41. Give reasons showing the superiority of mechanical ventilation over furnace ventilation.

Ans. A mechanical ventilator is more cheaply worked than a furnace; being placed on the surface, it can be readily inspected at any time; the amount of the ventilation can be regulated, so as to increase or decrease the air-current as required at any time; there is no danger from fire as with a furnace; there is no danger from an explosion of gas as with a furnace; there is no sulphuric acid engendered in the upcast, as is often the case with a furnace, which does so much damage

to tubbing, etc.; the workmen can do repairs in the shaft without disturbing the ventilation in the case of a mechanical ventilator, whereas they cannot do so with a furnace on account of the smoke.

42. When was the steam jet first applied as a means of producing ventilation in mines?

Ans. It was first applied in 1835, and the introduction of it was due to Mr. Goldsworthey Gurney.

43. How does the steam jet act in producing a current of air?

Ans. Its action has been explained in various ways (See Steam Jet, Chap. II.), but it may be sufficient to say here that steam is blown off perpendicularly up into the upcast shaft, at high pressure, from small orifices made in pipes, and the force, temperature and aqueous vapor aid in rarefying the ascending air.

44. Does it signify where the jets are placed in the upcast?

Ans. According to the late Mr. Nicholas Wood, who made elaborate experiments at a large number of collieries in the North of England in 1853, "On the relative value of the furnace and the steam jet"—"there does not appear to be any great difference in the mechanical effect, whether the jets are placed at the top or bottom of the pit."

45. How is it that the steam jet is not more frequently used in the ventilation of coal mines at the present time?

Ans. Because experiments have shown that in point of economy it has no comparison with other systems of producing air-currents.

46. How many feet of air should be mixed with one of fire-damp so as to render it harmless?

Ans. Thirty to forty.

47. Where should safety-lamps be used?

Ans. This may be answered by quoting what is enacted by the Anthracite Mine Law of Pennsylvania. By rule 9 of that Act we learn that "In every working approaching any place where there is likely to be an accumulation of explosive gases, or in any working in which danger is imminent from explosive gases, no light or fire other than a locked safety-lamp shall be allowed or used." The reader must acquaint himself with what is required in this respect by the law of the State or country in which he is engaged.

48. What precautions are necessary in blasting or firing shots in coal mines likely to contain inflammable gas?

Ans. Judgment should be exercised in the placing and direction of the hole: care should be taken in ramming, tamping or stemming the hole with suitable material: blasts should not be let off unless the coal is undermined. By Rule 11 of the Anthracite Mine Law of Pennsylvania it is required that "No blast shall be fired in any mine where locked safety-lamps are used except by permission of the mine foreman or his assistant,

and before a blast is fired, the person in charge must examine the place and adjoining places and satisfy himself that it is safe to fire such blast, before such permission is given." By General Rule 12 of the Coal Mines Regulation Act, 1887, of Great Britain, it is enjoined that "in places likely to contain either accumulations of gas or coal-dust, a shot shall not be fired unless the explosive is so used with water or other contrivance as to prevent it inflaming gas, or is of such a nature that it cannot inflame gas."

49. Will blasting by gunpowder cause an explosion?

Ans. Although the ordinary black powder is the best explosive for blasting coal, it gives off a certain amount of flame on explosion, and if there be any gas feeders it will ignite them at nearly every blast.

50. Will blasting by dynamite cause an explosion of fire-damp?

Ans. This explosive in its various forms is safer and less liable to ignite the gas than gunpowder, but as Mr. Williams, the Inspector for the 4th Anthracite District of Pennsylvania, says: "If a blast has less work to perform than is necessary to consume the energy of the explosive, it generates heat enough to ignite the fire-damp."

51. What are blown-out shots, and what dangers are connected with them?

Ans. Blown-out or gunned shots are such blasts as blow out the stemming or tamping without bringing down the coal, and are dangerous because under certain conditions they will produce explosions. It is now accepted that in some mines a blown-out shot, where coal-dust is present, will without any fire-damp cause an explosion. (See Chap. V.)

52. Which is more difficult to ventilate, an upbrow or downbrow place—that is, a rise or dip place? What forces are against or in favor of each case?

Ans. An upbrow is more difficult to ventilate than a downbrow; the light air always finds its way upwards, and the heavy air descends; fresh air is heavier than return air; these facts are in favor of ventilating the downbrow, and against the upbrow.

53. In driving a single place or underground channel in advance of the underground workings, how would you carry the air to the face?

Ans. By putting up brattice from the last opening, and so dividing the channel into two, or by putting in air-tubes, so that the air can go in one way and out the other.

54. Does the law require that the air-roads of a coal mine shall be of any specified size?

Ans. The law of the State of Tennessee, requires that "the intake air-way shall not be less than 20 square feet area and the return air-way not less than 25 square feet:" and in Prussia the section of the air-ways is dependent upon the quantities of air

necessary for the ventilation of the whole mine, including different splits, calculated upon a velocity of 13 feet per second for the fresh air-current, and of 22 feet per second for the return air-current.

55. How should air-doors be adjusted in an underground road?

Ans. According to the Anthracite Mine Law of Pennsylvania, "all doors used in assisting or in any way affecting the ventilation shall be so hung and adjusted that they will close automatically." The law is very similar, with respect to doors, in nearly all the coal mining States of the Union.

56. How are the barometer and thermometer used with respect to ventilation?

Ans. They are used to show the variation in the temperature and pressure of the atmosphere. According to General rule 33 of the Mine Law of Great Britain, a barometer and thermometer shall be placed above ground in a conspicuous position near the entrance to the mine.

57. How much does the atmospheric pressure vary by a difference of one inch in the reading of the barometer?

Ans. When the barometer rises an inch the pressure of the atmosphere is increased about 70 lbs. per square foot.

58. If the reading of the barometer at sea level be 30 inches, what will it read at 100, 200, 1,000 and 2,000 feet above sea level respectively?

Ans.	Inches.
At sea level	30.00
At 100 ft. above sea level	29.89
At 200 ft. above sea level	29.78
At 1000 ft. above sea level	28.89
At 2000 ft. above sea level	27.78

59. If the reading of the barometer be 30.5 inches at the top of a shaft, what will be the reading at the bottom. the depth being 1520 ft.?

Ans. By the rule given in Chap. II., under Barometer, we find that $\frac{1520\times30\cdot5}{26216}=1\cdot7$ will have to be added for the increased depth, then: $30\cdot5+1\cdot7=32\cdot2$ inches, the reading at the bottom.

60. When the mercury barometer stands at 30 inches, how will one of glycerine stand?

Ans. If we reckon the specific gravity of the mercury at 13·6 and the glycerine at 1·27, then the relative heights will be found thus:

$$\frac{30\times13\cdot6}{1\cdot27}=321\tfrac{1}{4}$$

61. If the thermometer reads 180 degs. Fahr., what will it read on the Centigrade scale.

Ans. ~~8·22 degs.~~

82. 2 deg.

62. If the thermometer reads 45 degs. Centigrade, what is that on the Fahrenheit scale?

ANS. 113.

63. Have any experiments been made showing the readings of the barometer contemporaneously with the issue of gas in mines.

ANS. Yes, in 1881, Mr. J. W. Corbett made extensive observations at Seaham Colliery on the subject and read a paper upon it before the North of England Institute of Engineers, on the 3d of July, 1883.

64. What knowledge do we gain from Mr. Corbett's observations?

ANS. In his concluding remarks he says: "One lesson suggested by the foregoing water-gauge, barometer and gas checking readings is, that as an instrument for the use of all connected with colliery operations, the water-gauge may be found to be preferable to the barometer, and that if a water-gauge is connected with a sealed-up working, its readings indicate nearly accurately the giving off or otherwise of gas in a colliery, which the barometer fails to do."

65. State the opinion of some other engineer on the connection of barometer readings and the escape of gas.

ANS. At the discussion of Mr. Corbett's paper referred to in the last question, Mr. J. Daglish said he might mention that many years ago he made a series of experiments at Hetton Collieries, with the view of ascertaining and recording the pressure of gas and the variations of the barometer, and the results he arrived at were precisely such as were given by Mr. Corbett, namely, that there was no connection whatever between the variations in the barometer and the prevalence of gas in the galleries of the mine, and that as Mr. Corbett had shown them, the gas appeared so long before the barometer indicated any change that practically it was of no value; indeed the gas had both come and disappeared before any variation in the atmosphere was recorded by the barometer.

66. Can the heights of mountains be ascertained by observing the boiling point of water?

ANS. Yes, the general rule is to reckon a fall of one degree on the Fahrenheit scale of the thermometer for every 530 feet of ascent. The following table gives examples of the comparative heights of certain places, readings of barometers and boiling points:

	Height above level of Sea. Ft.	Barometer, mean height.	Boiling point of water. Fahr. degs.
Quito	9541	20·75	194·2
Mexico	7471	22·52	198·1
St. Gothard	6808	23·07	199·2
Garonne (Pyrenees)	4738	24·96	203·0
Geneva	1221	28·54	209·5
Paris	213	29·69	211·5
Sea Level	0	30·00	212·0

67. Then, if the heights of mountains can be found by noting the point of ebullition, cannot the depths of mines also be ascertained in the same way?

Ans. The boiling point of water and other liquids depends on the pressure under which they are evaporated; as we ascend a mountain less heat is required, and as we go down a mine greater heat is required before ebullition commences, but as a variation in the barometer of 1 inch only represents a difference of half a pound pressure per square inch, no accuracy in the measurement of the depths of mines could be attained by this plan. Supposing the barometer to rise 1 inch for each 150 fathoms of descent, then at 3600 feet this would represent an increase in the pressure of about 2 lbs. per square inch. The table annexed shows the boiling points of water at the pressures given:

Temperature Fahrenheit degs.	Pressure per Square inch. lbs.	Temperature Fahrenheit degs.	Pressure per Square inch. lbs.
32	·089	158·	4·51
50	·178	176·	6·86
68	·337	194·	10·16
86	·609	212·	14·70
104	1·06	230·	20·80
122	1·78	240·8	25·37
140	2·88	248·	29·88

68. What is the weight of air in a room 30 ft. long, 22 ft. wide, and 15 ft. high, with temperature at 62 degs.?

Ans. The weight of a cubic foot of air at 62 degs., according to Table VIII., Chap. V., is ·0763122 lb.; then $30 \times 22 \times 15 \times ·0763122 = 755·49$ lbs., the weight of the air.

69. What will be the weight of the oxygen contained in the room mentioned in the previous example?

Ans. As air contains 23 per cent. by weight of oxygen, and as the room referred to contained 755·49 lbs. of air, the weight of the oxygen will be found by saying as 100 is to 755·49 so will 23 be to 173·76; thus—

$$\frac{755{\cdot}49 \times 23}{100} = 173{\cdot}76 \text{ lbs.}$$

70. Westminster Hall is 290 ft. long, 68 ft. wide, and 110 ft. high; what is the weight of the air in it, the temperature being 62 degs.?

Ans. The weight of a cubic foot of air, according to Table VIII., Chap. V., is ·0763122. Then

$$\frac{{\cdot}0763122 \times 68 \times 290 \times 110}{2{,}240} = 73{\cdot}9 \text{ tons.}$$

71. How many cubic feet of air at a temperature of 50 degrees will weigh 1 lb.?

Ans. By the table, the weight of a cubic foot of air at this temperature is ·0788863. Dividing these figures into one will give the answer:

$$\frac{1}{{\cdot}0788863} = 12{\cdot}67 \text{ cubic feet.}$$

72. What is the weight of a column of air resting on a table 6 feet by 3 feet 6 inches?

Ans. Nearly twenty tons, but this weight does not press upon the table, because it is met by a corresponding pressure upwards from the air below the table, due to the weight of all the surrounding air.

73. What is the cause of gob-fires and how are they to be prevented?

Ans. Gob-fires are occasioned through leaving small coal in the gobs or goaves; the action of the oxygen upon the finely-divided coal causes it to heat and eventually fire. The best way to prevent them is to have all the coal or slack removed, or to have the gob filled up. The plan of putting down bore-holes from the surface and filling up the gob with the culm from the dump has been successfully performed at two or three collieries in the anthracite regions of Pennsylvania. The object of this was to prevent subsidences, but it would be effective in preventing the accumulation of gas in the gobs as well.

74. Is coal dust explosive?

Ans. Experience in coal mining both in the Old World and the New leaves now no longer any doubt that the dust of some coals will explode, and that a serious explosion of dust may occur from a blown-out shot or gunned blast. So far as we know, however, whether an explosion will occur or not by a blown-out shot much depends upon the chemical composition of the coal and other circumstances. Mr. G. M. Williams, the inspec-

tor of mines for the Fourth Anthracite district of Pennsylvania, says: "We have not yet found that the dust of anthracite coal promotes explosions, but it may assist to intensify the heat of the gases in an explosion; and if it does, the expansion is enhanced and a greater force is developed increasing its destructive power."

75. It has been stated that flour dust will explode: do you believe this to be the case, and can you give the chemical composition of flour?

ANS. Many instances are on record of flour dust exploding from a naked light. The following is an analysis of wheat:

Carbon	461
Oxygen	434
Hydrogen	58
Nitrogen	23
Inorganic matter	24
	1,000

76. How does carbureted hydrogen issue from a coal mine?

ANS. In many cases gradually from the coal beds, in some cases it accumulates by degrees in the gobs or goaves, in other cases it comes off suddenly in large volumes under great pressure from the coal itself or associated strata.

77. Does any other gas issue suddenly from the rocks into mines besides fire-damp?

ANS. Yes, carbonic acid has frequently come off in blowers from the working face at the Rochebelle collieries in France, with a crackling noise like that produced by the issue of fire-damp. On one occasion three men were killed there and two others had a narrow escape. The volume of gas was sufficient to foul 176,583 cubic feet of air in a few minutes, and issued with such force that 74½ tons of coal were blown down. It took 4½ days to clear the pit from gas.

78. Under what conditions will carbureted hydrogen explode?

ANS. When mixed with atmospheric air so that the fire-damp forms one-eighth to one-ninth part of the whole, it is then in the highest degree explosive.

79. How is the presence of carbonic acid gas detected?

ANS. A lighted candle is perhaps the easiest detector of this gas, as when it exists in the air to the extent of 10 per cent. the light will be extinguished. Anyone going into this gas would soon be suffocated.

80. How is the presence of sulphureted hydrogen gas ascertained?

ANS. The presence of this gas is readily detected by the peculiar smell it has of rotten eggs.

81. How much oxygen does a man consume in twenty-four hours?

ANS. Nearly 27 cubic feet.

82. What gas is found immediately after an explosion of fire-damp?

Ans. After-damp; this gas consists of 8 parts of nitrogen, 2 of a gaseous vapor, and one of carbonic acid. In some cases when the nitrogen is in large proportion the lamp will burn, although the men or horses will be killed in breathing it.

83. What is binoxide of nitrogen? State some of its properties.

Ans. Binoxide of nitrogen ($N O_2$) is a colorless gas; it has the remarkable property of instantly absorbing oxygen from the air, and becoming thereby converted into a brownish red vapor of nitrous acid ($N O_3$), which possesses a highly suffocating odor.

84. Give some particulars of sulphurous acid gas.

Ans. This is one of the products of blasting; a light will not burn in it, and miners are occasionally destroyed by it when it mixes with carbonic oxide and other vapors caused by the spontaneous combustion of coal in gobs or goaves.

85. What is meant by laughing gas? State some of its properties.

Ans. This is protoxide of nitrogen, which is a colorless, odorless gas, having a somewhat sweetish taste. It is a powerful supporter of combustion, and a piece of ignited charcoal will burn in it almost as brilliantly as in oxygen. When respired it produces a sort of intoxication of a most exhilarating character; hence it has commonly received the name of laughing gas.

86. Explain what is meant by *Ignis fatuus*; state where it is to be seen, and explain the cause of the display of the phenomenon.

Ans. *Ignis fatuus* means "a silly light." It is a meteor or light which appears in the night in meadows or marshy grounds, and is known by the name of "Will o' the Wisp," or "Jack o' the Lantern." It is occasioned by an ascent from the earth of phosphoreted hydrogen gas, derived from animal and vegetable remains, and has the peculiarity of igniting itself in the air.

87. Is there any relation between coal and wood in chemical composition?

Ans. There is a relation, indeed a similarity, but as coal becomes mineralized it loses the lighter gases and retains a larger proportion of carbon; so that at each stage of mineralization coal has more and more carbon until we come to anthracite, which we find contains over 90 per cent., whereas wood only contains about 50 per cent.

88. What is ammonia, and where is it most frequently met with?

Ans. It is a volatile compound of nitrogen and hydrogen found in all liquids obtained in the dry distillation of nitrogenous bodies. It is to be found in abundance in some underground stables. Ammonia is set free in grinding guano.

89. It is said that in the neighborhood of Findlay four bore-holes yielded about 20 million cubic feet of natural gas daily. Supposing this had to be substituted by manufactured coal gas, how many tons of coal would be required per annum for the purpose, and how many acres of a seam 5 feet thick would have to be mined to supply it?

ANS. Reckon one ton of coal to yield 11,400 cubic feet of gas, and one acre of coal 1 ft. thick to contain 1,500 tons.

$20{,}000{,}000 \times 365 = 7{,}300{,}000{,}000$ cubic feet of gas issuing from bore-holes annually.

$$\frac{7{,}300{,}000{,}000}{11{,}400} = 640{,}350$$

tons of coal required to manufacture the gas,

$$\frac{640{,}350}{5 \times 1500} = 85\tfrac{1}{3},$$

the area in acres of a seam of coal 5 ft. thick required to supply it.

90. At a colliery in Pennsylvania the volume of air passing is 74,580 cubic feet per minute with $\frac{4}{10}$ of an inch of water-gauge. What is the power of the ventilation?

ANS. $\dfrac{74{,}580 \times \cdot 4 \times 5{\cdot}2}{33{,}000} = 4.7$ H. P.

91. At a colliery in the bituminous regions of Pennsylvania, the volume of air in the intake was 54,000 cubic feet per minute, but the quantity in the workings was only 29,400. How is the difference to be accounted for?

ANS. No doubt some of the quantity would escape to the return at the stoppings erected in the break-throughs, some probably would be allowed to pass through the gob, etc.

92. At one of the mines in the Second Bituminous district of Pennsylvania the upcast is 7 feet diameter; what is the velocity of the air in feet per second, when the quantity is 35,680 cubic feet per minute?

ANS. Area of shaft $= 7 \times 7 \times \cdot 7854 = 38{\cdot}484$, then

$$\frac{35{,}680}{38.484 \times 60} = 15{\cdot}45 \text{ feet per second.}$$

93. At one of the collieries in Pennsylvania, the air-shaft is 9 feet diameter; what is the velocity of the air in feet per second with a quantity of 23,843 cubic feet per minute passing.

ANS. Area of shaft $= 63{\cdot}617$ square feet. Then

$$\frac{23{,}843}{63{\cdot}617 \times 60} = 6\tfrac{1}{4} \text{ feet per second.}$$

94 At a certain colliery, the shaft is 6 feet diameter, and the quantity of air passing 17,600 cubic feet per minute; what is the velocity of the air in feet per second?

Ans. Area of shaft = 28·274 feet, then

$$\frac{17{,}600}{28{\cdot}274 \times 60} = 10{\cdot}24 \text{ feet, per second.}$$

95. Two air-ways of the same length are 3 feet and 4 feet diameter respectively, what is the comparative pressure and power required to pass the same quantity of air through each?

Ans. The pressure or power required to pass the same quantity of air through round airways of the same length is in inverse ratio to the 5th power of their diameters:

5th power of 3 = 243.
5th power of 4 = 1024.

then the pressure or power will be in accordance with these numbers or,

$$\frac{1024}{243} = 4.214 = \text{as 1 is to } 4{\cdot}214.$$

96. If the barometer stands at 28·4 inches, find the pressure on a square inch?

Ans. The height of barometer in inches × .4908, the weight of a cubic inch of mercury, will give the result, thus: 28·4 × ·4908 = 13·93 lbs.

97. When the mercurial barometer stands at 29·75 inches, what is the height of the barometer formed of a liquid whose specific gravity is 5·5?

Ans. The specific gravity of mercury being 13.568 then

$$\frac{29{\cdot}75 \times 13{\cdot}568}{5{\cdot}5} = 73{\cdot}4 \text{ inches.}$$

98. If the elastic force of a mass of gas whose volume is 1000 cubic feet be 30·275 inches of mercury, find its elastic force if it be allowed to expand to a volume of 3870 cubic feet.

Ans. 7·823 inches.

99. In an air-way 7 feet by 5 feet, passing 12,000 cubic feet per minute, what is the velocity of the air-current per second?

Ans. 5·71.

100. How long will it take a current of air measuring 18,000 cubic feet per minute to pass through an air-course 1½ miles long, 7½ feet high, and 8 feet wide?

Ans. The area of air-course will be 8 × 7½ = 60. The velocity of current will be $\frac{18{,}000}{60}$ = 300 ft. per minute or $\frac{300}{60}$ = 5 ft. per second. The length of air-course is 1760 × 1½ × 3 = 7920 ft. The time in passing will be $\frac{7920}{5}$ = 1584 seconds or $\frac{1584}{60}$ = 26 minutes 24 seconds.

101. If the barometer reads 30 inches at the surface, what will it show at a depth of 2,000 feet below the surface?

Ans. By the rules given under the heading *Barometer* in Chap. II., $I = \frac{D \times B}{26.216}$ therefore $\frac{2000 \times 30}{26,216} = 2{\cdot}21$ and $30 + 2{\cdot}21 = 32{\cdot}21$, the reading of barometer at the depth of 2000 feet.

102. If the modulus of the machinery producing the ventilation be ·62, what horse-power must it perform in maintaining a volume of 120,000 cubic feet of air per minute with a water-gauge of 1·39 inches?

Ans. $\frac{120,000 \times 1{\cdot}39 \times 5{\cdot}2}{33,000 \times {\cdot}62} = 42.39$ H. P.

103. The quantity of air required to ventilate a mine is 120,000 cubic feet per minute; if the upcast shaft be round, what should be its diameter so that the velocity of the current will be 500 feet per minute?

Ans. The area of shaft should be $\frac{120,000}{500} = 280$ square feet and the diameter would be $\sqrt{\frac{280}{{\cdot}7854}} = 18{\cdot}86$.

104. If the water-gauge of a ventilating fan be one inch when running at 50 revolutions per minute, what will the water-gauge be when the fan is running 90 revolutions?

Ans. As $50^2 : 1 :: 90^2 = 3.24$ inches.

105. In the event of an explosion of fire-damp in a coal mine, what course should be pursued in entering the mine to rescue the employés?

Ans. As the result of an explosion is generally to blow down stoppings, doors and air-bridges, thereby deranging the ventilation, and producing an unbreathable atmosphere called after-damp, the first thing to consider is the restoration of the ventilation. The effects are very various, depending on the force of the explosion, and the extent and condition of the mine. The mode of proceeding will depend very much on these circumstances, but in any case the exploring or rescue party should be careful to take fresh air in along with them as they proceed into the mine, which they should do by the downcast, and for lights, safety-lamps should be used. Circular iron tubes made from thin sheet, 9 inches to 18 inches in diameter, and 6 feet to 12 feet long, may be readily used for this purpose, or canvas tubes made of the same material as brattice cloth, kept dilated by internal iron hoops, placed at regular intervals, may be used. A waterfall made to operate constantly from the top of the shaft down the downcast, may prove of advantage if the means of producing an air current have failed. Presuming that the stoppings in the "break-throughs" are blown down,

these should be rebuilt as the rescue party proceeds along the intake, and one end of the tubes referred to should be passed through into the return, and the other end carried into the mine until the next break-through is reached. The air will go in by the intake road and go back through the tubes to the return air-way; the next stopping when it is reached, should be rebuilt and the tubes connected through this with the return air-way again, and carried forward to the next, and so on. Doors likewise should be replaced where necessary, and the air-bridges restored, but as to what is exactly required to be done will depend upon the exigencies of each particular case, and the means at hand for aiding in the rescue. Care, promptitude and forethought are all important. A rescuer may go forward some little distance in advance of the air by putting Glauber salts in a small muslin bag, and placing this over the mouth; in breathing, the deleterious gases are by this means to some extent absorbed. He should take care, however, not to go too far in advance of the air or he will probably fall down in the after-damp, the breathing of which benumbs the faculties, disturbs the mind, and casts a deadly lethargy over the whole body. A breathing apparatus called a *respirator*, constructed to assist in the exploration of mines after explosions, may be used. There are various kinds of respirators, of which one or two of a very efficient character were exhibited to the audience at a lecture, delivered by Sir Frederick Abel, on "Accidents in Mines," in 1887, before the Institute of Civil Engineers, London. One from Prussia was notable, devised by Mr. Loch, to enable an explorer to go a short distance into a mine and remain there; the respirator being connected by means of a pipe with the external air.

106. If 10,000 cubic feet of air pass a circular channel of 12 feet diameter, how much will pass in one having a diameter of 6 feet?

Ans. The quantities will be in inverse ratio to the cube roots of the fifth powers of their diameters, or

$\sqrt[3]{\frac{12^5}{6^5}} = 3{\cdot}1748$ so that the quantity in this case will be

$$\frac{10{,}000}{3{\cdot}1748} = 3150.$$

107. If the efficiency of a ventilating fan be 60 per cent. and the indicated horse-power of the engine working it 40; how much air will be circulating with the water-gauge at 1·6 inches?

Ans. $\frac{{\cdot}60 \times 40 \times 33{,}000}{1{\cdot}6 \times 5{\cdot}2} = 95{,}192.$

108. What is the weight of 2,000 cubic feet of air at 50° F. under a pressure of 29·5 inches of mercury?

Ans. $W = \frac{1{\cdot}3253 \times 29{\cdot}5 \times 2{,}000}{459 + 50} = 153{\cdot}62$ lbs.

109. If the water-gauge be 1½ inches, what is the ventilation pressure in feet of air column (M) with mercury at 30 inches and temperature at 62° F.?

Ans. As water is 817·1 times heavier than air at this temperature (See Table XXV., Chap. V.) and as the water-gauge is expressed in inches, and the motive column in feet, we get $\frac{817\cdot1}{12} = 68\cdot1$ as the factor, then $M = 68\cdot1 \times 1\cdot5 = 102\cdot15$ feet.

110. There are 10,000 cubic feet of air passing per minute along an air-way having a rubbing surface of 24,000 feet, and area 20 feet, what will be the water-gauge, the co-efficient being ·01 lb. per square foot for a velocity of 1,000 feet a minute?

Ans. $\frac{10,000}{20} = 500 = \frac{1}{2}$ a thousand $= .5$, then

$\frac{\cdot01 \times 24,000 \times \cdot5 \times \cdot5}{20} = 3$ lbs. per square foot pressure, therefore, the water-gauge will be $\frac{3}{5\cdot2} = \cdot57$ inch.

111. If the indicated horse-power of an engine operating a fan be 40, and the horse-power of the air be 28, what is the percentage of useful effect?

Ans. $\frac{100 \times 28}{40} = 70$ per cent.

112. If a fan at 40 revolutions per minute produce 80,000 cubic feet of air with a water-gauge of 2 inches, what is the horse-power of the ventilation; and if the quantity of air be increased to 100,000, what will then be the horse-power in the air, the water-gauge, and the revolutions of the fan?

Ans. $\frac{80,000 \times 2 \times 5\cdot2}{33,000} = 25\cdot21$ H. P. The revolutions will be in accordance with quantity, therefore, 50. The pressure and consequently the water-gauge is according to the velocity squared. Then

as $8^2 : 2 :: 10^2 = 3\cdot12$ inches, the water-gauge with the increased quantity, and $\frac{100,000 \times 3\cdot12 \times 5\cdot2}{33,000} = 49\cdot16$, the horse-power with the increased quantity.

113. If the return air-course becomes contracted in area, what effect has it upon the water-gauge and the quantity of air, the ventilating power remaining the same?

Ans. The water-gauge will rise and the quantity of air will decrease.

114. What method would you adopt for obtaining a large amount of air with but a small water-gauge?

Ans. I would have the shafts and air-ways of a large size, by which the velocity of the current would be reduced.

115. What is the greatest range that has been noted in the temperature of the atmosphere?

Ans. About 130° above and 40° below zero are the extremes in the United States East of the Mississippi; and 65° below in the Northwest at surface level. It is stated that —81° has been observed in northeast Siberia and +101° in the shade in Paris, and +153° in the sun at Greenwich Observatory, both in July, 1881. It has frequently exceeded +100° in the shade at Philadelphia during recent years, all Fahrenheit scale.

116. What is the range of temperature in a coal mine?

Ans. About 130° is about the greatest range that can occur under normal conditions. The average temperature of a coal mine depends on the depth the galleries lie below the surface. The temperature in the workings or galleries of a colliery is pretty constant all the year round. The coldest part of a mine is at the bottom of the downcast in winter, when on some occasions it is probably as low as —30°; the highest temperature the writer has experienced in the interior of a coal mine is about 100°. In case of a gob-fire the temperature would be likely to rise to 200° or 300°.

117. Is there any rule by which the temperature may be calculated from the depth?

Ans. By experiments it has been found at different places that the temperature increases with the depth, but the rate of increase is not always the same at different places. From observations made in a bore-hole in Germany put down to a depth of 5,628 feet, it was found that the regular rate of increase in temperature was 1° F. for each 67·2 feet in depth: from the readings made at this very deep hole the following formula has been deduced for calculating the temperature at different depths.

$$F = 50{\cdot}68 + \frac{D - 19{\cdot}68}{67{\cdot}2}$$

in which D = depth in feet.

118. At what temperature in air can a human being exist?

Ans. In answering this we will use the Fahrenheit scale. According to A. de Parville, a French authority, a man can endure a range of temperature of 252°, that is from —94° to 158°. The attendants in the Paris Hammam Baths remain 10 hours a day in rooms which are heated up to 158°, 176°, or even 194°; Parville on one occasion remained 15 minutes in a sweating room, in which the dry air had been heated by his orders up to 251·6° from which he went direct into a basin of water at 53·6°, so that in less than a minute his body experienced a difference of temperature of 198°. Tillaux and Duhamel bore the heat of an oven at 263·8° for three minutes. Prince Henry of Orleans in his travels over the mountains of Central Asia experienced a

temperature of —40°. Captain Burck found in Fort Reliance the temperature to be —70°, and Captain Douran found —89·7° in Fort Ran in April; Lieutenant Peary and his wife in wintering in McCormick Bay, in 1889 to 1890, noted a temperature of —96°, and their health was not seriously affected by experiencing a temperature varying from —22° to —58° for three months.

119. What is the range of atmospheric pressure within which a human being can live?

Ans. A man can breathe and exist best at the normal atmospheric pressure of 30 inches of mercury, equal to 14·72 lbs. per square inch. He can barely exist at a heighth of seven miles where the pressure is only one-fourth of that at the surface. A man can breathe and work for some hours under a pressure of 2½ atmospheres or 37½ lbs. per square inch, as in a diving bell, but under a greater pressure paralysis may be produced; some work, however, was done at St. Louis Bridge by men under a pressure of 63·7 lbs per square inch.

119. Do changes of the temperature affect the ventilation of a mine? If so, how?

Ans. Yes. When the temperature of the outer air, which enters the mine by the downcast, becomes lower than that of the mine, being heavier, it increases the ventilating pressure, and consequently improves the ventilation. An increase in the temperature of the outer atmosphere has the contrary effect.

120. How can the number of doors be reduced in a coal mine?

Ans. By dividing the air-current and having a separate split or division of air for each district, and building air-crossings or air-bridges.

121. If an airway measuring 7 ft. × 7 ft. has a quantity of 30,000 cubic feet of air passing per minute, what should be the dimensions of a square road to pass 55,000 cubic feet per minute with the same pressure?

Ans. As in square roads the quantities are according to the square roots of the fifth powers of the lengths of the sides, with the same pressure, the length of the sides will be according to the square of the fifth root of the quantities, therefore in this case we may say:

As $$\left(\sqrt[5]{30}\right)^2 : 7 :: \left(\sqrt[5]{55}\right)^2 : 8{\cdot}91.$$

$$\left[\sqrt[5]{30} = 1{\cdot}974 \text{ and } \sqrt[5]{55} = 2{\cdot}228.\right]$$

or, as the quantities are in the proportion of 6 to 11, we may say:

As $$\left(\sqrt[5]{6}\right)^2 : 7 :: \left(\sqrt[5]{11}\right)^2 : 8{\cdot}91.$$

$$\left[\sqrt[5]{6} = 1{\cdot}431 \text{ and } \sqrt[5]{11} = 1{\cdot}615.\right]$$

or, as the quantities are likewise in proportion to 60 and 110, then we may say again :

As $$\left(\sqrt[5]{60}\right)^2 : 7 :: \left(\sqrt[5]{110}\right)^2 : 8{\cdot}91.$$

$$\left[\sqrt[5]{60} = 2{\cdot}268 \text{ and } \sqrt[5]{110} = 2{\cdot}56.\right]$$

and as a proof, the pressure for the air-way 7 ft. square, and that 8·91 ft. square will be found to be the same by the rule :

$$\frac{k\ s\ v^2}{a}$$

122. What is meant by the *motive column*, and how is it calculated?

Ans. It means the pressure in operation to produce the ventilation, expressed in feet of air-column or head of air ; or a column of air of such a height as to equal in weight the difference between the weight of the air in the downcast and upcast. It is calculated by the following formula :

$$M = D \times \frac{T - t}{459 + t}$$

M = motive column, D = depth of upcast in feet, t = temperature of downcast, T = temperature of upcast, the result of which gives the feet of air-column at the temperature of the air in the upcast.

$$D \times \frac{T - t}{459 + T}$$

will give the length of the motive column in feet of air at the temperature of that in the downcast, but it is usual to find the motive column for the air in the upcast.

The motive column may likewise be found by taking the weight of a cubic foot of air at the temperature of the downcast and upcast, and from these figures finding the difference of the weight of the air in the two shafts.

123. What is the motive column under the following conditions : Temperature of downcast 50° F., upcast 130° F., and depth of shaft 300 feet?

Ans. $300 \times \frac{130 - 50}{459 + 50} = 47{\cdot}15$ feet, or

weight of one cubic foot of air at 50° = ·0781113
" " " " " 130° = ·0675020

then
$300 \times {\cdot}0781113 = 23{\cdot}43339$
$300 \times {\cdot}0675020 = 20{\cdot}25060$
Difference = 3·18279

$$\frac{3{\cdot}18279}{{\cdot}067502} = 47{\cdot}15 \text{ as above.}$$

124. If 100 cubic inches of air weigh 31 grains troy under a

barometric pressure of 30 inches, what will the same quantity of air weigh at a higher altitude where the barometer stands at 26 inches, the temperature being the same?

Ans. The volume of air varies inversely as the pressure, the temperature remaining constant, therefore, the diminished pressure is to the original pressure as the original volume is to the increased volume, or as $26 : 30 :: 100 : x$.

The increased volume of air at the higher altitude where the barometer is 26 inches, though the temperature is the same,

$$\text{is} = x = \frac{30 \times 100}{26} = 115{\cdot}4 \text{ cubic inches.}$$

At this altitude, therefore, it takes 115·4 cubic inches of air to weigh 31 grains troy; hence 100 cubic inches would weigh

$$\frac{100}{115{\cdot}4} \times 31 = 26{\cdot}86 \text{ grains.}$$

125. What units of work are necessary to overcome the friction of an air-way 6 feet square, 1,000 feet long, when the quantity passing is 10,800 cubic feet per minute?

Ans. $U = \frac{k\ s\ v^2}{a} \times q = 6{,}480.$

126. If, with a pressure represented by one inch of water-gauge, 30,000 cubic feet of air pass, what height will the water-gauge be when the quantity passing is 50,000?

Ans. As $3^2 : 1 :: 5^2 = 2{\cdot}77$ inches.

127. If 5 H. P. circulate 30,000 cubic feet of air, how many H. P. will be required to circulate 50,000?

Ans. As $3^3 : 5 :: 5^3 : 23{\cdot}14$.

128. Here are 100,000 cubic feet of air passing through two separate air-courses, one having five times the resistance of the other, how much will pass through each?

Ans. The quantity of air is according to the reciprocal of the square root of the length. In this question one may take the resistance as the length,

then the relative quantities will be as $\sqrt{\frac{1}{5}}$ and $\sqrt{\frac{1}{1}}$

or as 4472 : 1, then the quantities will be 69,098 and 30,902 respectively.

129. If the average percentage of oxygen in the air is taken at 20.7 volumes, what will be the explosive maximum of $C H_4$ if two volumes of $C H_4$ require for their complete combustion 4 volumes of oxygen?

Ans. Two volumes of $C H_4$ require 4 volumes of oxygen, therefore 1 volume of $C H_4$ will require 2 volumes of oxygen, and 20·7 volumes of oxygen will require 10·35 of $C H_4$ or fire-damp. This mixed with the air containing 20·7 of oxygen and 79·3 of nitrogen will make up altogether 110·35 parts. Then as 110.35 : 10·35 :: 100 : 9·38, so that the maximum explosibility of

fire-damp is when it is contained in the air to the extent of 9·38 per cent.

130. A ventilating fan working at 30 revolutions per minute gives a water-gauge of eight-tenths of an inch, what will be the speed of the fan when the water-gauge reads two inches?

Ans. The quantity of air passing, and consequently the speed or number of revolutions of the fan, varies as the square root of the water-gauge, therefore,

$$\sqrt{\frac{2}{\cdot 8}} \times 30 = 47{\cdot}4 \text{ revolutions.}$$

131. If 9 cubic feet of gas be exploded, how many cubic feet of flame will it make?

Ans. It is calculated that one cubic foot of gas expands to 21·3 cubic feet of flame, therefore $9 \times 21{\cdot}3 = 191{\cdot}7$ cubic feet.

132. What kind of stoppings are required by law? How would you construct them under various conditions?

Ans. By rule 2 of the Bituminous Mine Law, Pennsylvania, 1893, the mine foreman shall cause all stoppings along the airways to be properly built. If for a temporary purpose I would erect them with deal boards, say an inch thick; but when required permanently I would fill up the "break-through" with loose stone or rock for some yards, and at each end would build up a wall with brick and cement. By the Anthracite Mine Law all crosscuts shall be substantially closed with brick or other suitable building material laid in mortar or cement whenever practicable, but in no case shall the air stoppings be constructed of plank except for temporary purposes.

133. What precautions would you take to tap water from abandoned workings, to conform to law, and to secure the greatest safety to the men employed in the mine; and from what source could a mine foreman obtain useful data to give him an idea of the extent of the danger to be encountered?

Ans. I should proceed in the manner laid down in Sections 3 and 4, Article IX, of the Bituminous Mine Law, 1893, and not work within 50 feet of any abandoned mine containing a dangerous accumulation of water or gas. Remove the danger by driving a drift protected by bore-holes. A mine foreman would get useful data by consulting the map of the mine which is being approached.

134. What are the lawful duties of a mine foreman?

Ans. According to the Bituminous Mine Law of Pennsylvania; he shall see that the regulations prescribed for each class of workmen under his charge are carried out in the strictest manner possible, that stoppings are properly built, that in road grades there shall be a sufficient width between car and rib, that undermining be done before blasting, that in fiery mines the ventilating furnace, when put out, be not relighted except in his presence, that in case of accident to the ventilating fan the men be withdrawn from the mine. The mine fore-

man shall measure the air current at least once a week at the inlet and outlet and at or near the faces. He shall give prompt attention to the removal of all dangers reported to him by the fire-boss or any other person, and when a fire-boss is not employed he or his assistant shall visit and examine every working place at least once every alternate day.

135. State in detail what are the necessary qualifications to make an efficient mine foreman, as required by law.

Ans. By the Bituminous Mine Law of Pennsylvania, candidates for a mine foreman's certificate of competency shall be at least 23 years of age, and shall have had at least 5 years practical experience after 15 years of age; shall be citizens of the commonwealth, men of good character, and of known temperate habits, and be able to pass the examination for a certificate of competency.

136. A mine has four splits, and the amount of air in each split is as follows: 1st split, 6,000 feet, 2nd split, 7,050 feet; 3d split, 7,800 feet; 4th split, 9,750 feet. State how many persons could be employed in each split under the different lawful requirements? And if the air-ways are all 7 ft. by 5 ft., what would be the velocity in each air-current?

Ans. The law requires 100 cubic feet of air per man per minute, ordinarly, or 150 feet, where fire-damp has been detected. Then in the 1st split 60 men and 40 men respectively could be employed; in the 2nd split 70 and 47 respectively; in the 3d split 78 and 52 respectively; in the 4th split 97 and 65 respectively.

The velocity of the air in each split would be

$$1\text{st}\ \frac{6000}{7 \times 5} = 171 \text{ ft. per minute.}$$

$$2\text{nd}\ \frac{7050}{7 \times 5} = 201 \text{ ft. per minute.}$$

$$3\text{rd}\ \frac{7800}{7 \times 5} = 223 \text{ ft. per minute.}$$

$$4\text{th}\ \frac{9750}{7 \times 5} = 279 \text{ ft. per minute.}$$

137. If the ventilation of a mine was insufficient, and the ventilating power was working up to its full capacity, what would you do under such conditions to increase the ventilation?

Ans. The airways must be increased in area, or the current divided into more splits or separate currents. Dividing a current of air, passing through one air-way, into different splits, has the same effect as increasing the area of the original airway.

138. Explain fully the principle involved in natural and artificial ventilation.

Ans. See question 33.

139. Explain how you would ascertain the entire weight of air in a ventilating shaft.

Ans. Ascertain the average temperature of the air. Then the weight of a cubic foot is found by the rule

$$W = \frac{1{\cdot}3253 \times B}{459 + t.}$$

This multiplied by the depth of the air in feet will give the weight or pressure of the air in pounds.

140. What is a water-gauge? What are its uses in mines? How is the constant of 5·2 determined? What useful information is given to the mine foreman by the use of this instrument in mines?

Ans. The water-gauge is a glass tube 8 or 10 inches long bent in the shape of the letter **U**; when used it is partly filled with water. It is used to ascertain the difference of pressure of the air in two roads separated by a partition in which the gauge is inserted. As one cubic foot of water weighs 62·5 lbs. at ordinary temperature, then a square foot of water one inch deep weighs

$$\frac{62{\cdot}5}{12} = 5{\cdot}2$$ therefore the difference

in inches in the height of the water in the two legs, multiplied by this constant 5·2, will be the difference in the pressure per square foot of the air acting on the water in the two separate legs of the gauge. By noting the reading of the water-gauge, the mine foreman will know whether any doors have been left open to allow the air to take a short cut, or whether any obstruction has occurred in the air-course.

141. If the velocity of an air-current going at the rate of 7 feet per second had to be increased to 14 feet per second, how much would the ventilating power have to be increased to produce the increased rate?

Ans. It would have to be increased eight times. The power is according to the cube of the velocity, therefore

$$\left(\frac{14}{7}\right)^3 = 2^3 = 8$$

142. In what proportion does friction increase and decrease relative to the flow of air through the mine passage-ways? Illustrate by examples, by what means the density of air is increased and diminished?

Ans. The friction or resistance is increased with the length of the road and according to the square of the velocity. If with one inch of water-gauge the velocity is 5 feet per second, the water-gauge would be 2 inches with a velocity of 7·07 feet per second. The density of the air diminishes in proportion to the length of the air-channel.

143. If the air-ways of a mine were to be increased to double

their length, other conditions remaining the same, in what proportion would you have to increase the ventilating pressure to produce the same volume of air?

Ans. By increasing the length to double, the resistance is doubled. The ventilating pressure would have to be doubled to produce the same volume of air.

144. What mode of ventilation reduces the dangers of an explosion and reduces the friction? State the reason it is so.

Ans. By having separate air-currents for each district, the friction is reduced and the result of an explosion is likely to be limited to the district in which it takes place. The friction is reduced because in splitting, an advantage is gained similar to that obtained by increasing the area of the air-course.

145. Show by a sketch, a system of ventilation, which, in your opinion would produce the best distribution of air in a mine, and would obviate the excessive use of doors, in order to secure the best sanitary results and the most economical operations of the mine.

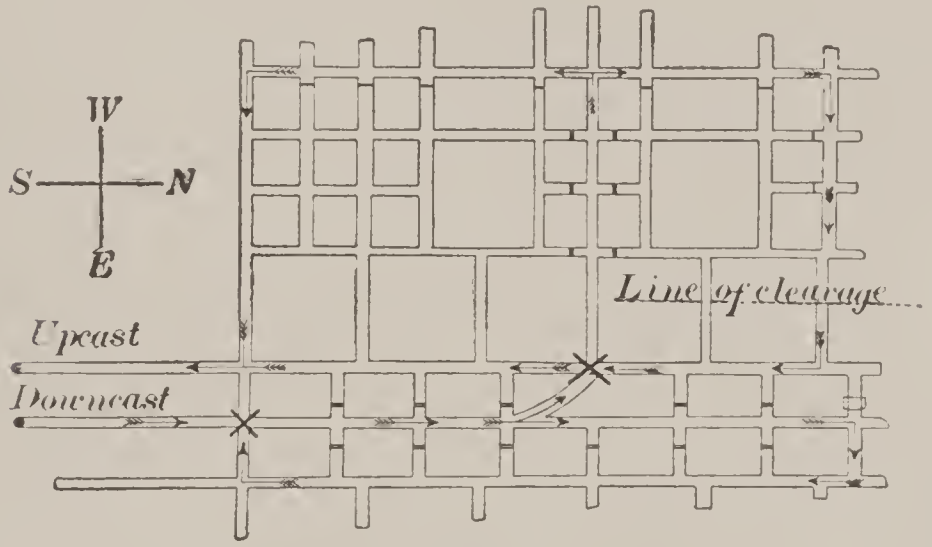

Fig. 7.

Ans. The air may be divided or distributed in the manner shown on annexed sketch, Fig. 7, which shows a method of mining coal by "board and pillar" practiced in the northern coal field of England. This method or a modification of it is adopted in flat lying seams at a depth of about 900 feet. The boards driven westward are 4 yards wide and the pillars left are about 20 yards x 24 yards. The arrows show the direction of the air currents, and the haulage roads are all in the intake. It is intended that the workings on the east side be laid out in a similar way to these on the west, so that the different air currents would be nearly equally divided. By this plan each district would get fresh air and the doors required would be reduced to the least possible number.

146. What are the inexplosive gases found in mines? How

are they produced? Where are they found? What effects are they likely to have upon the workmen? How are they detected? What are their specific gravities and composition? And what would be your remedies to render them harmless?

Ans. *1. Carbon dioxide.* This is known by the name of carbonic acid, stythe, blackdamp and chokedamp. It is composed of one atom of carbon combined with two atoms of oxygen, and has a specific gravity of 1·525. It is produced naturally in mines by the breathing of animals, the combustion of lights, and by the firing of explosives, and is commonly given off in many mines. It acts upon the human system by making breathing difficult, and induces a sleepy feeling; men have frequently fallen down in it and slept to death. A candle will not burn in it, and it is detected from this.

2. Carbon monoxide, known as carbonic oxide, and white damp. It consists of one atom of carbon chemically combined with one atom of oxygen, specific gravity ·975. It is produced when incomplete combustion takes place, and is found where gob fires occur. It is known by its sweet odor and deadly results. It makes the legs tremble of those who breathe it, affects the head and causes insensibility: as little as two per cent. will cause death. A light will burn well in it, but the flame will not become elongated until it forms 12½ per cent. of the aerial surroundings. With a certain mixture of atmospheric air it will explode.

3. Sulphureted hydrogen. This is composed of two atoms of hydrogen chemically combined with one atom of sulphur, and has a specific gravity of 1·19. It is detected by the strong offensive smell it has. With a certain mixture of atmospheric air it will explode.

4. After-damp. This is a mixture in a mine resulting from an explosion of fire-damp. It consists of carbon dioxide, carbon monoxide, nitrogen and steam in varying proportions.

The proper remedy to render these different gaseous mixtures harmless is a copious supply of fresh atmospheric air.

147. What qualifications should a man possess, so as to make a good, reliable "fire-boss"?

Ans. By the Bituminous Mine Act of Pennsylvania, a fire boss shall be at least 23 years of age, and have had at least 5 years' practical experience after 15 years of age as a miner; have a good moral character, and be of known temperate habits, and by examination demonstrate his fitness to perform the duties of fire-boss.

He should have a practical knowledge of the gases met with in mines, and know how to conduct a suitable current of air through the various ramifications of a mine.

148. What is the first duty of a "fire-boss" when he enters the mine?

Ans. By rule 9 of the Bituminous Mine Law of Pennsylvania, he shall enter the mine before the men have entered it and

before proceeding to examine it, he shall see that the air current is traveling in its proper course?

149. What are the lawful duties of a fire-boss?

ANS. By rules 10 and 11 of the Bituminous Mine Law, he shall not allow any person except those duly authorized to enter or remain in any part of the mine through which a dangerous accumulation of gas is being passed in the ventilating current from any other part of the mine. He shall frequently examine the edges and accessible parts of new falls and old gobs and air-courses, and he shall report at once any violation of this act to the mine foreman.

150. Describe the structure of the safety-lamp, and show on what principle its safety depends.

ANS. Davy, in experiments he made before constructing his lamp, concluded that when a flame of an oil lamp was surrounded by a cylinder of gauze having 784 meshes to the square inch, the heat given off by the flame was distributed so rapidly by its contact with the fine iron wire gauze, which is a good conductor of heat, that the temperature of the cylindrical gauze remained too low to ignite an explosive mixture outside the gauze. This principle, to some extent at least, applies to all safety-lamps, although now in most lamps, in order to have a better light, a glass tube or cylinder surrounds the flame, the gauze being placed only at the upper part of the lamp.

151. Describe the instruments that are most useful in aiding the "fire-boss" in determining the conditions of the mine.

ANS. The water-gauge, which will show him, when placed in a partition between the intake and return, if there is any change in the pressure of the air; the anemometer which will give him the velocity of the air current; and the safety-lamp which will enable him to ascertain whether firedamp is present or not.

152. What are the explosive gases found in coal mines? Describe their properties, composition, specific gravities, how and where are they produced in mines, and under what conditions do they become explosive?

ANS. *1. Methyl hydride*, or light carbureted hydrogen, $C H_4$, specific gravity .555, composed of 24.6 per cent. by weight of hydrogen and 75.4 per cent. of carbon. When 9½ per cent. of this gas is contained in the air it is highly explosive (See question 129). It exudes naturally from many coal seams and their adjacent strata.

2. *Olefiant gas*, $C_2 H_4$, has a specific gravity of .9784; a mixture of about 94 per cent. of air and 6 per cent. of this gas will be explosive. Under certain proportions of admixture with air, carbonic oxide and sulphureted hydrogen are also explosive.

153. How would you proceed to look for and detect explosive gases in mines?

ANS. By using a safety lamp and observing the color and

form of the halo of the flame inside the lamp. With pure fire-damp the cap or halo is elongated and blue.

154. How do you ascertain the additional amount of gas that is given off in the mines when the barometer falls from 30 inches to 29 inches?

Ans. Fire-damp is elastic, and will expand in bulk as the pressure is reduced, so that gas contained in a gob, supposing it to measure, say 1,000 cubic yards, will expand to

$$\frac{30 \times 1000}{29} = 1{,}034,$$

on the atmospheric pressure being reduced from 30″ to 29″. The amount of gas that would exude from an acre of gob, 3 feet high, would be 44 cubic feet on a diminution of the atmospheric pressure represented by .001 of an inch on the barometric scale.

One would naturally think that the rate of the issue of gas from the solid coal would depend on the pressure at which it is contained in the coal, but according to the Royal Commission on Accidents in Mines, Great Britain, the outflow of gas from holes is not proportional to the maximum accumulation of pressure. In any case, at whatever pressure the gas is present in the solid coal, I am of opinion that by a reduction of the outside pressure from 30″ to 29″, no material difference will take place in the issue of gas from the coal face in a mine. Bearing on this subject, the Royal Commission of Great Britain say, "The absence of a general connection between colliery disasters and barometric changes is practically established"; and again Professor Chatelier says: "The influence of barometric variations is always very small."

155. In what stage of the mining operations do the most accidents occur from explosions of fire-damp? Explain fully.

Ans. According to the Report of the Prussian Fire-Damp Commission, out of 1,633 explosions:

3·8 per cent. occurred in explorations in stone.

60·4 per cent. occurred in explorations and in winning coal.

34·1 per cent. occurred in working or mining coal.

1·7 per cent. occurred at other points in mine.

From this it is to be concluded that explosions take place in the coal mines of Prussia mostly in opening out a mine, but I am under the impression that in the "board and pillar" working of Northumberland and Durham, more explosions occur in working out the pillars than in exploring headings. There is a general impression amongst some miners that the greatest amount of gas issues from coal seams in opening the mine by exploring headings, but on this point Professor Chatelier says: "It is impossible to determine at present the period in the work when the greatest discharge of gas occurs."

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